

Chemistry  
Murphy

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REVIEW

OF

CHEMISTRY FOR STUDENTS.

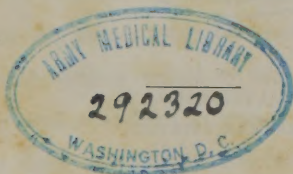
ADAPTED TO THE COURSES AS TAUGHT IN THE

PRINCIPAL MEDICAL SCHOOLS

OF THE

UNITED STATES.

BY JOHN G. MURPHY, M.D.



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Annex

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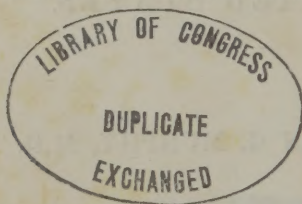
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## PREFACE.

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THE author of the present little work, having experienced a difficulty, both as regards time and amount of matter, in reviewing his chemical knowledge from the larger and more comprehensive treatises of chemistry, has, for the purpose of obviating the same, which may probably oppose others in prosecuting their chemical studies, deemed it expedient to offer it for their perusal.

It is not offered to the student as a text-book, but merely, as its name indicates, as a review, to be used in connexion with a course of lectures, or with some of the large and standard treatises on the subject. At the same time, however, it will be found to embrace, in a condensed form, most of the principal facts relating to the elementary bodies, and many of the compounds

of those elements; besides containing a short account of the subject of natural philosophy, in the first few pages.

If it serve the purpose of lightening one of the many labours of the medical student, the design of the author will be most happily accomplished.

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# REVIEW OF CHEMISTRY.

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## PART I. PHYSICS.

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### SECTION I.

#### GENERAL LAWS.

THE whole domain of nature is embraced by intellectual and physical truths. It is the latter with which we have to deal under the name of physical science; it is divided thus:—

#### PHYSICAL SCIENCE.

##### *Natural History.*

Zoology,  
Botany,  
Mineralogy,  
Anatomy.

##### *Natural Philosophy.*

Mechanical Philosophy,  
Chemistry,  
Geology,  
Physiology.

By the table we see that physical science arranges and classifies external phenomena; its two first great divisions being *Natural History* and *Natural Philosophy*; the former of which describes and groups external bodies, while the latter reasons on their relations in the order of cause and effect.

Natural History is subdivided into Zoology, Botany, Mineralogy, and Anatomy, which are mere sciences of classification and arrangement.



Natural Philosophy divides itself into Mechanical Philosophy, which investigates bodies undergoing no change of structure; Chemistry, which investigates bodies undergoing change; Geology, which studies the functions of great mineral masses, and their relations in the order of time; and, lastly, Physiology, which studies the functions of anatomical parts. It is impossible, however, to draw the exact lines between each of these, they blend so much together.

#### OF FORCES.

Force is the cause of any physical change or alteration in a body, or in its relations; as magnetic force attracting the needle, &c.

There are two great forces, viz.: *attraction* and *repulsion*. Present the needle to the magnet, and it is attracted in one position and repelled in another; the science investigating these phenomena is called *magnetism*, and the phenomena themselves take place at appreciable distances. But present A to B, and the two disappear as such, while a new compound body is formed entirely differing from both, and the phenomena take place at inappreciable distances; then the laws investigating these facts is called chemistry, and the force a chemical one. Here it may be necessary to state, however, that there is no such thing as actual contact.

Bodies are divided into *solids*, *liquids*, and *gases*. *Solids* are those the particles of which adhere with a force called *cohesive*, such that it requires force to separate them; yet the particles are not in actual contact, which is proved by the fact, that all bodies are elastic; and this could not be, were there no spaces for the particles to move in. Solids differ very much in regard to this property of elasticity, but still all are to a certain degree elastic. If we break a piece of caoutchouc, which is one of the most elastic bodies, we must

first carry its particles beyond the region of their attractive forces, that is, to a point of repulsion.

*Repulsion.*—This is a modification only of elasticity; attraction and repulsion are conditions only of equilibrium between the particles. This is illustrated by suddenly cooling a melted globule of glass in water (Prince Rupert's drops); the external part cooling more rapidly than the internal of course contracts, and the internal particles are thus compressed within the limits of repulsion; hence when we break the surface, which is done by the slightest touch, the inner particles repel each other very suddenly as soon as freed, and the glass is broken up into minute dust.

Liquids and gases are also elastic. It has been asserted that the ultimate atoms of liquids were spheres; if this were the case the atoms would by compression lose their spherical shape and ultimately become solid; thus we can compress mercury,  $\cdot 00000265$  of its bulk, alcohol  $\cdot 00002165$ , water  $\cdot 00004665$ , &c., yet none of them can thus be made solid.

Concerning the ultimate atoms of bodies, we really know nothing; there is no limit to divisibility: hence we speak of molecules, corpuscles, &c., instead of atoms.

*Gravity.*—The force of gravity differs from the molecular forces of matter by occurring at appreciable distances; it is this that makes all bodies have weight; and double the matter gives double the gravitating force or weight. All bodies fall to the *centre* of the earth, because a line to the centre is a diagonal between the equal forces existing on both sides of that line. The great law of gravity is, *that the attraction is directly as the quantity of matter, and inversely as the square of the distance*; hence a body when projected from the earth, is uniformly retarded in its ascent, and uniformly accelerated in its descent.

*Capillarity.* Water and other fluids manifest different powers of wetting substances; thus if water is spread on glass, it will wet it uniformly, or if one end of a porous piece

of paper is dipped in water, it will by degrees wet the whole of the paper; but if the water be placed on greasy paper it will not wet it, but it will collect itself into globules, which thus present the least points of contact for the whole amount of fluid. The two former cases are due to attraction, while the latter is due to a repulsion of the body for the water. These phenomena belong to capillary force, which has been defined to be, that exerted by fine tubes on a liquid, causing it to be elevated in the tubes above the level of the surrounding liquid, while the height of that elevation depends on the diameter. But this force is not confined to tubes, for if we place a plate of glass in water it will ascend on the sides of the plate, or if we place the same plate in mercury, the latter will be depressed below its level; hence all the phenomena are really due to attraction and repulsion. When tubes are used, however, the fluid will rise and its surface will be concave or meniscoid; while the height to which it rises depends, as has been said, on the calibre of the tube; that is, *the elevation or depression of the liquid is inversely as the diameter of the tube.*

Capillarity will not occur in a tube one end of which is closed, nor when the surface of the tube is wet.

Plates of glass touching at one edge, dipped in water, with the touching edges vertical, will cause the water to rise in a curved line, the highest point of which is where the edges are in contact. Capillarity is not modified by the density of the liquid.

*Endosmose.*—Two liquids having an attraction for each other will mix when placed in the same vessel, as alcohol and water; but those having no mutual attraction will not, as oil and water. If now a moist membrane be interposed between two liquids of the first kind, which liquids have also an affinity for the membrane, they will still mix, by passing through it, but the rapidity with which the one enters the other will be modified by the membrane, which thus destroys the equi-



librium which previously existed between the liquids. The general law is, *that the rarer liquid passes more rapidly into the denser than the latter into the former.* Two conditions, however, are necessary. 1st. That the fluids, as water and brine, have an affinity for each other; and 2d, that they have an affinity for the membrane. Endosmose is therefore not a property of capillarity really, but it depends on the relation existing between the surface of the liquid and the membrane.

*Diffusibility of Gases.*—Gases will mix, no matter what their densities, affinities, or other modifying circumstances may be, and this will take place even when dry, porous substances are interposed.

The law by which gases diffuse themselves into each other, is *that the diffusion is inversely as the square roots of the densities.*

TABLE OF DENSITY AND DIFFUSIVE POWER OF SOME AIRS.

	Density.	Diffusive Power.
Air, . . .	1.000	1.000
Oxygen, . . .	1.105	.946
Nitrogen, . . .	0.972	1.014
Hydrogen, . . .	0.069	3.807

From the above table it will be seen, that when hydrogen and air are placed under the proper conditions for endosmotic action, that the former would pass into the latter four times as rapidly as the latter into the former. This law is a very important one in physics; for it is by means of it that the nitrogen, oxygen, and carbonic acid gases of atmospheric air are so intimately mixed. It is also very important physiologically as regards the elimination of carbonic acid, and the absorption of oxygen by the lungs. In this case, however, the law regarding the densities is modified, for carbonic acid gas passes out of the lungs more rapidly than air passes in, because the air cells are moist or wet membranes; under

other circumstances, as when the membrane is dry, the reverse would be true, on account of the greater density of carbonic acid gas compared with air. This is proved experimentally by using moist caoutchouc as a diaphragm between the two airs. A new case therefore arises, which is, *that those gases which have the greatest affinity for water, and are most condensible, have the greatest diffusibility when placed in relation to wet membranes.*

#### DENSITY AND SPECIFIC GRAVITY.

The great law of gravity is, that attraction is directly as the quantity of matter; from this it would be inferred that all bodies when let fall from the same height, would arrive at the earth at the same moment. This is, however, not the case, because some being light, that is, contain little matter in proportion to their bulk, meet with more resistance from the air than those which are heavier. This difference is due to their different *densities* or *specific gravities*, by which is meant their weight compared to their bulk, or to the same bulk of some other body which is reckoned as unity. In practice it is found most convenient, for solids and fluids, to take water as the standard of comparison, because it can always be got of a uniform condition by distillation.

*Specific Gravity of Liquids.*—To obtain the specific gravity of liquids, it is only necessary to weigh equal bulks of the liquid used and water, at the standard temperature, and then divide the weight of the liquid by the weight of the water.

A bottle with a ground glass stopper is used, capable of holding 1000 grains of distilled water at 60° F.; the height to which the water rises in the bottle is then marked, and the whole is accurately weighed. The specific gravity of any other fluid can now be got, by pouring it into the bottle to the 1000 grain mark, and then weighing it; of course its weight will be its specific gravity compared with water.

Thus the bottle will hold 1850 grs. of sulphuric acid at the same temperature, viz.,  $60^{\circ}$  F., hence its sp. gr. is 1850, or 1.85, water being 1.

*Specific Gravity of Gases.*—This is obtained by comparing the gases with dry atmospheric air at  $60^{\circ}$  F.; 100 cubic inches of which weigh 31.0117 grs. The method is to exhaust a globe of glass whose capacity is 100 cubic inches, and then introduce the gas and weigh it; then divide the weight of the gas by the weight of an equal amount of air, and the quotient will be the sp. gr. of the gas.

*Specific Gravity of Solids.*—If a vessel is taken whose area is 100 square inches, and filled with water, and then a pressure exerted of 20 pounds on a square inch, of the surface of the water, the pressure will be multiplied by every square inch of surface the vessel contains, that is, 20 pounds by 100, for the whole pressure in the vessel; hence the hydrostatic law that the distribution of pressure is equal in all directions.

Again, when a solid is immersed in water, the total pressure made by the water on it, is equal to the area of its surface multiplied by the depth of its centre of gravity below the surface of the fluid. But the *upward* pressure exceeds the *downward* pressure by the *weight* of the displaced fluid; hence when a body is weighed in water, its weight will be less in water by as much as the weight of the volume of water displaced.

This can be proved by actual experiment, by using a hollow cylinder, having an accurately fitting solid piston filling its whole calibre; now take out the piston and suspend it by a hook to the cylinder, and attach both to one end of a beam which has weights at the other end, for the purpose of balancing the cylinder and piston. Now place the piston in water, while it is still attached; the balancing weights at the other end of the beam will descend, and the equilibrium is restored by filling

the cylinder with water, the volume of which is just equal to that of the piston, which has displaced its own bulk of water in the vessel used.

To obtain then the specific gravity of a solid, *divide the weight in air by the loss in water*; thus 100 grains of brass will lose 12 grains when weighed in water, then  $100 \div 12 = 8.33$ , the sp. gr. of brass.

The conditions of equilibrium between a body that is immersed and one that floats, are different. The first displaces its *volume*, the latter only its *weight* of water; because when a body floats, it takes the place of the liquid which was maintained in its position on the surface of the water, by the distribution of pressure; and hence the *floating body* must be supported by precisely the same *means*, and its *weight* must equal that of the *displaced fluid*.

To obtain the sp. gr. of a floating body, it is first weighed and then attached to a piece of metal heavy enough to sink it, and suspended from a balance. The whole is then weighed, immersed and weighed again. The difference between the two weighings gives the weight of a quantity of water equal in bulk to both. The piece of metal alone is now weighed in air and water. These give the data for getting the sp. gr. We present an example:

Light body, as cork, weighs in air . . . .	39.6 grains.
Attached to brass the whole now weighs . . .	519.6
Immersed in water the whole now weighs . . .	294.1
Weight of water equal in bulk to both . . . .	<hr/> 225.5
Weight of brass in air . . . . .	480
Weight of brass in water . . . . .	422
Weight of equal bulk of water . . . . .	<hr/> 58
Bulk of water equal to cork and brass . . . .	225.5
Bulk of water equal to brass alone . . . . .	58
Bulk of water equal to cork alone . . . . .	<hr/> 167.5

Weight of cork 39·6, divided by weight of equal bulk of water 167·5, is equal to 0·236, the sp. gr. of cork.

When a heavier body is placed on a floating body, it will sink the latter further, and the weight of the displaced fluid is equal to the new weight added. It is on this principle that *hydrometers*, *urinometers*, &c., are constructed.

These generally consist of hollow vessels, as cylinders, with a stem arising above the surface of the fluid in which they float. Weights are added above, which sink the instrument to a mark on the stem; and this weight may be supposed to be 400 grains; now it is wished to ascertain the weight of a five-dollar gold piece. Place it above and add weights until 400 grains have been completed; to do so 282 grains are required; hence the weight of the coin is  $400 - 282 = 128$  grains. Now remove it from above and place it in such a position that it will be immersed; it will now weigh less by the weight of its own volume of water, and the mark will rise above the surface, requiring additional weights to sink it to the same mark, which in the case considered are 7 grains. Divide 128 by 7, and we get 18, the sp. gr. of American coin; pure gold being 19.

By this instrument the sp. gr. of different liquids can also be ascertained; thus the depth to which the stem sinks in water is known, and by calling that zero, we can have the stem graduated above and below, indicating known increments or diminutions of weight; then transfer to a heavier or lighter liquid, and by inspecting the scale, its specific gravity is known by observing the height of the fluid on the stem.

#### PHYSICAL CONSTITUTION OF AIRS AND GASES.

It was long ago discovered by the Florentine Academicians that water would not rise in a pump above thirty feet. Torricelli supposed that the water was sustained by a force which



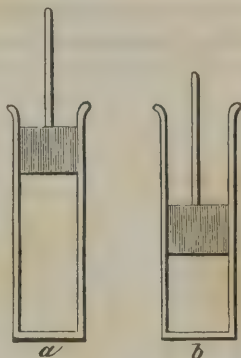
he thus demonstrated. A tube fifty inches long, closed at one extremity, was filled with mercury, and the open extremity plunged in a basin of the same liquid; the mercury descended in the tube, till it reached a point thirty inches above the surface of the mercury in the basin. Torricelli now inferred that it could be no other than the pressure of the atmosphere on the surface of the mercury in the basin that sustained the column, and this was made more evident to him when he saw it descend as he shortened the superincumbent column of air by going up mountains, and ascend as he descended from them. He also saw that a column of mercury one inch high sustained a column of water thirteen and a half inches, and therefore a column of thirty inches would sustain a thirty-four feet column of water; hence the same force that sustained a thirty inch column of mercury, also sustained nearly thirty-four feet of water in the common pump, allowing for friction, &c. These experiments long ago proved that we live at the bottom of an aerial ocean, which pervades everything at the surface of the earth, and exerting a force which is demonstrated to be fifteen pounds on every square inch of surface on the earth. The whole subject is referred to what is called atmospheric pressure.

That the weight of a column of air is fifteen pounds on every square inch, is proved by taking a tube whose area is one inch square, and weighing the column of mercury supported in it; it is found to be fifteen pounds.

An instrument carefully constructed on these principles is called a *barometer*; it is for the purpose of measuring the weight of the air at the surface; which weight varies owing to meteorological causes. The rise and fall of the mercury is called its sweep; in our latitude the sweep is about three inches. The space above the mercury in the barometer is a perfect vacuum as regards air, and is called the Torricellian vacuum.

*Elasticity of Airs and Gases.*—Gases differ from solids in

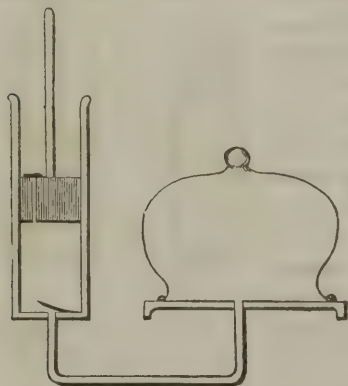
not having their particles placed within attractive distances; they are hence very elastic. If air be placed in a cylinder with a piston moving air-tight, and the piston be moved down, the pressure will diminish the volume of air; if the piston be raised, the air will expand and fill the whole space, no matter how extensive it may be; hence the *law, the volume of air or gas is inversely as the compressing force* to which it is subjected, and therefore *the density and elastic force are directly as the pressure and inversely as the volume*. For instance, 100 cubic inches of gas under a pressure of thirty inches of mercury, would expand to 200 cubic inches if the pressure were reduced one half, or shrink to 50 cubic inches if the pressure were doubled. This is called the law of Mariotte, and it has been proved true for twenty-seven atmospheres.



By using a glass tube forty or fifty inches long, closed at one end, which is bent up like a fish-hook, and then pouring in mercury till it reaches a certain height in both limbs, which heights are marked, the pressure on each surface will be fifteen pounds; now if thirty inches more of mercury are added in the long limb, the volume of air which is confined in the bent limb will be diminished one half, and its pressure or tension will be double, because it sustains an additional weight of fifteen pounds on a square inch, or thirty pounds.

On this principle of the elasticity or expansibility of airs, the air-pump is constructed. This consists of a cylinder, which connects by means of a pipe with a receiver, or any vessel to be exhausted. In this cylinder is a piston, having

a valve opening upwards; at the bottom of the cylinder is another valve opening upwards, while at the receiver there may be another valve opening downwards. If now the piston be raised, the valve on its surface is closed by the pressure of the atmosphere, and a vacuum is created in the cylinder; the air in the vessel to be exhausted now expands, and forcing



open the other valves fills the cylinder; the piston is now made to descend, the lower valve is closed by the pressure of the air in the cylinder, and the valve in the piston for the same reason is opened, allowing the air to escape; and in this way by successive strokes a vessel may be nearly exhausted; not entirely, because there is always some air left,

due to the expansion of a small portion to fill the whole apparatus, and because the tension of air becomes so small as finally not to force open the valves. This is also proved by exhausting air over mercury, which will never rise to thirty inches, because a perfect vacuum cannot be created above its surface, by an air-pump.

That the elastic *force* or *tension* of air is equal to the pressure is obvious; if this were not the case, bottles containing air, and indeed everything would collapse. The fact is rendered very striking by placing an hermetically sealed Florence flask in a receiver and then exhausting the receiver; the flask bursts outwardly, because pressure is removed from the outside, and the elastic force of the air within, which



is equal to the original pressure without, and therefore fifteen pounds to the square inch, is sufficient to break the bottle.

As the barometer measures the weight of a column of air, it follows that by ascending, the mercury will fall, owing to the diminution in length of the superincumbent column, and of course its weight also. By this means the height of mountains can be measured; thus, let two observations be made at the same moment of time, one on the top and the other at the base of the mountain, noticing also the temperature (for which a correction has to be made); then the difference between the heights of the mercury in the two barometers, will indicate the height of the mountain, remembering that a fall of one inch indicates an elevation of 922 feet nearly; but this only is true near the level of the sea. As we ascend, the pressure diminishes very rapidly in proportion to the ascent, that is, as we ascend *arithmetically* the pressure diminishes *geometrically*.

At the level of the sea the barometer stands at 30 inches.

5,000 feet above	.	.	.	.	24.797
10,000 "	.	.	.	.	20.497
15,000 "	.	.	.	.	16.941
3 miles	.	.	.	.	15.000 $\frac{1}{2}$
6 "	.	.	.	.	7.50 $\frac{1}{4}$
9 "	.	.	.	.	3.75 $\frac{1}{8}$
12 "	.	.	.	.	1.875 $\frac{1}{16}$
15 "	.	.	.	.	0.937 $\frac{1}{32}$

## SECTION II.

### CALORIC.

THE sensation produced in us by a hot body is called *heat*, and the cause of that sensation is termed *caloric*.

Heat and cold are relative terms depending on conditions of the body, and the relative climates in which we may be living; these sensations are therefore very bad means of measuring temperature; and we must hence resort to some uniform and constant condition, the best being the volume which a body occupies at different temperatures.

The great general law is *that bodies are expanded by heat and contracted by cold.*

The subject of caloric is studied under the following heads:

1. Expansion of bodies and the laws regulating it.
2. The relations of dissimilar bodies to temperature.
3. Liquefaction.
4. Vaporization.
5. Distribution of caloric.

In order to ascertain the relative expansions of bodies, the temperatures to which they are exposed must first be known; this is learned by the thermometer, which as it is intimately connected with the subject will be treated of now.

#### THERMOMETERS.

The first thermometer was invented by Sanctorius. Its principle was very simple, air being the only material used for expansion. It consists of a glass tube with a bulb blown on one end and open at the other; the air in the bulb is then expanded by heat, and the open extremity is plunged in a coloured liquid. As the bulb cools the air in it condenses, and the coloured liquid then rises in the tube. It is obvious now that as the air in the bulb is affected by heat or cold, the height of the column of liquid in the tube will vary, and a measurer of temperature is thus had. But this instrument is liable to many objections, not the least of which are, that its expansions and contractions are too great, to measure any considerable changes in temperature, and it is modified by

meteorological changes, or in other words, that it acts as a barometer as well as a thermometer.

Other thermometers have been invented, besides the one last described, but the best are those in present use, namely, the mercurial thermometer. Mercury is the very best material that has yet been discovered, because its expansions are uniform, and its boiling and freezing points are very remote from each other.

In making a thermometer it is necessary to have a very fine and uniform capillary tube; then melt the glass at one end and blow a small bulb on it, by means of a caoutchouc bag at the other. The mercury, which should be pure and free from moisture, is now introduced by rarefying the air within the ball by heat, and then dipping the open end of the tube in that fluid; as the bulb cools the mercury rises, and a small portion is by these means got into the bulb; the bulb is now again heated, and the whole of the tube is filled with the vapour of mercury, when it is again plunged with its open mouth in the mercury, and the bulb with about one-third of the tube thus filled. The bulb is again heated, and when the mercury has reached the top of the tube, it is suddenly and hermetically sealed by means of a blow-pipe flame.

The instrument must now be graduated, and to do this two fixed points can readily be obtained, viz.: 1st. The temperature of boiling water, which is nearly always the same, and 2d, the temperature of liquefying snow or ice. Having ascertained the height of the mercury at these two temperatures the scale can be graduated as desired.

Fahrenheit laid off this interval into 180 degrees, the first of which or the freezing point he called  $32^{\circ}$ , while the boiling point would then be  $212^{\circ}$ . Fahrenheit named his freezing point  $32^{\circ}$ , because he discovered that the mercury in his thermometers (which contained 1122 parts), expanded  $\frac{1}{32}$  part of its volume, in ascending from the temperature of Ice-

land (which he supposed the coldest that could be produced), to the freezing point. The idea, however, that this zero was the greatest cold that could be produced was erroneous.

Besides Fahrenheit's scale there are the centigrade and that of Reaumur; the former of these is the most convenient in practice; its boiling point is  $100^{\circ}$ , that of melting snow is the zero or beginning of the scale, and the interval is divided into 100 parts. The same interval in Reaumur's scale is divided into 80 parts, and in Fahrenheit's into 180 parts, because  $212^{\circ}$  is his boiling point, and  $32^{\circ}$  the freezing point, and  $212^{\circ} - 32^{\circ} = 180^{\circ}$ .

To change the indication of temperature from one scale to the other, requires nothing more than a simple proportion; thus one degree on the centigrade is larger than one on the Fahrenheit scale, in the proportion of 180 to 100 or 9 : 5; and of Reaumur in the proportion of 180 to 80 or 9 : 4. To reduce  $212^{\circ}$  F. to the centigrade, first subtract  $32^{\circ}$ , which leaves  $180^{\circ}$ , then  $180 \times \frac{5}{9} = 100^{\circ}$  C.; to reduce  $212^{\circ}$  F. to Reaumur,  $212^{\circ} - 32^{\circ} = 180^{\circ} \times \frac{4}{9} = 80^{\circ}$  R.

#### EXPANSION.

When a body is heated, its molecules are endowed with a repulsive force, and are therefore removed a greater distance from each other; in other words, the body expands.

Expansion is opposed to cohesion, and therefore those bodies possessing the greatest cohesive force, must be expanded the least. Solids have this force in the greatest degree, liquids less, and aeriform bodies least of all; hence the expansion of solids is small, that of liquids greater, and that of gases the greatest of all.

*Expansion of Solids.*—The solids, as has been said, are the least expansible of the three great classes of bodies, and of the solids the metals are the most expansible. Different solids do not expand to the same degree from equal additions

of heat; but their dilatation (at least of the more permanent ones) is very uniform within certain limits; for instance, their expansion from  $32^{\circ}$  to  $122^{\circ}$ , is equal to what takes place between  $122^{\circ}$  and  $212^{\circ}$ . But it has been proved that solids expand in an increasing ratio for very high temperatures.

RECTILINEAR EXPANSION OF SOME SOLIDS FOR A RANGE OF  $180^{\circ}$ .

Glass . . . . .	$\frac{1}{1284}$	of its length.
Copper . . . . .	$\frac{1}{582}$	
Brass . . . . .	$\frac{1}{532}$	
Iron . . . . .	$\frac{1}{815}$	
Gold . . . . .	$\frac{1}{661}$	
Silver . . . . .	$\frac{1}{524}$	
Tin . . . . .	$\frac{1}{462}$	
Lead . . . . .	$\frac{1}{351}$	

Knowing the rectilinear expansion, *the whole expansion is obtained by multiplying by three.*

There is no relation at all existing between the expansibilities of solids and their other properties, as weight, hardness, ductility, &c.

*Expansion of Liquids.*—Different liquids expand differently, nor is there any relation existing between their expansibilities and their other properties, as volatility, &c. The same liquid also expands differently for equal increments of temperature; that is, the same liquid will expand more from  $122^{\circ}$  to  $212^{\circ}$ , than from  $32^{\circ}$  to  $122^{\circ}$ . Mercury is rather an exception to this rule, for it undergoes the most uniform expansion of any liquid known; by experiment it is found to dilate  $\frac{1}{53}$  of its bulk from  $32^{\circ}$  to  $212^{\circ}$ , but between  $212^{\circ}$  and  $392^{\circ}$  it expands  $\frac{1}{54 \cdot 25}$ , and between  $392^{\circ}$  and  $572^{\circ}$ ,  $\frac{1}{53}$  of its bulk.

The height at which the mercury stands in the thermometer does not indicate its absolute expansion, it is only the difference between its expansion and that of the glass; but the

glass is a corrective for the increasing expansion of the mercury above  $212^{\circ}$ , and the thermometer is almost absolutely correct.

EXPANSION OF SOME LIQUIDS FROM  $32^{\circ}$  TO  $212^{\circ}$ .

Alcohol	.	.	.	.	.	$\frac{1}{9}$ of its volume.
Nitric Acid	.	.	.	.	.	$\frac{1}{9}$
Fixed Oils	.	.	.	.	.	$\frac{1}{12}$
Ether	.	.	.	.	.	$\frac{1}{14}$
Sulphuric Acid	.	.	.	.	.	$\frac{1}{17}$
Water	.	.	.	.	.	$\frac{1}{23}$
Mercury	.	.	.	.	.	$\frac{1}{33}$

Heat affects the bulk of some fluids peculiarly, and instead of causing them to expand, has the effect of contracting them, if applied at certain temperatures. Water is the most remarkable example of this class. Ice swims on the surface of the water, and therefore must be lighter than it, proving that the water must expand at the time of freezing. This increase is estimated to be about  $\frac{1}{9}$  of its volume. The maximum density of water is fixed at  $40^{\circ}$ , and when cooled below or heated above this, it expands. The cause of this expansion is ascribed to a new arrangement of its particles.

*Expansion of Gases.*—It was supposed at one time, and not a very remote period, that all gases expanded equally, and that the expansion of any one from  $32^{\circ}$  to  $212^{\circ}$ , was the same for all; this, however, is not the case; each differs from the other, although the dilatations are very nearly alike.

One hundred cubic inches of air at  $32^{\circ}$  becomes, as has been ascertained by experiment, 136.6 cubic inches at  $212^{\circ}$ , that is, one degree has expanded it  $\frac{1}{490}$  of its entire volume; this ratio, viz.,  $\frac{1}{490}$  of the bulk at  $32^{\circ}$ , is very nearly true for all gases, and is therefore adopted for all. If now 490 measures at  $0^{\circ}$  will become 491 measures at  $1^{\circ}$ , and 492 at  $2^{\circ}$ , the volume of a gas at any degree can be readily obtained, provided its original measure is known.



Meas. at 50°.	Meas. at 60°.	Meas. at 50°.	Meas. at 60°.
Thus, 540	: 550	:: 100	: 101·85.

TABLE OF EXPANSION OF GASES FROM 32° TO 212°.

Air	. . . . .	·36650
Hydrogen	. . . . .	·36706
Carbonic Oxide	. . . . .	·36688
Carbonic Acid	. . . . .	·37099
Cyanogen	. . . . .	·38767
Sulphurous Acid	. . . . .	·39028

WINDS.

The expansibility of air by heat gives rise to the phenomena of winds. One-third of the heat of the sun is lost in the atmosphere, but the rest of it serves to supply our planet with the requisite amount of heat; the earth being a non-conductor becomes much heated in those places on which the rays strike vertically, as at the equator, while the comparative coolness of our middle latitudes is due to the oblique direction of the sun's rays on us, allowing most of them to be reflected. Again, the temperature of the planetary spaces according to calculation is  $-54^{\circ}$  F., and we infer the temperature of the poles to be the same very nearly. Now as the temperature of the equator is very warm, and that of the poles very cold, it follows that the air at the equator will be rarefied and rise, forming a partial vacuum, and the cold heavy condensed air from the poles will rush in to fill its place, and this latter in its turn undergo the same process; this will create two currents or winds from the poles towards the equator, that is, there will be north and south winds. The earth at the equator moves with the velocity of 1000 miles an hour, but the velocity of any given point above or below is less, until the poles are reached, where it is nothing, hence the air or wind coming from these points will have an oblique direction from east to west, because the earth moves from west to east; these winds are called the *trade winds*. It will

also be seen that where these two winds meet at the equator, they will neutralize each other, and we have there the *region of calms*.

Ventilation is founded on the same principles; the chimney or ventilator should be divided by a partition, so that a current of heavy air may settle down on one side to occupy the place of the rarefied air ascending on the other.

#### THE RELATION OF DISSIMILAR BODIES TO TEMPERATURE, OR SPECIFIC CALORIC.

The thermometer points out accurately the difference in the temperature of any two bodies, but it does not tell how much heat any body contains; thus it stands at the same height in a tumbler of water, as it does in the spring from which the tumbler was taken, though they contain different amounts of heat, yet indicating the same temperature.

Heat copper, silver, tin, &c., and they will not be raised to the same temperature by the same amount of heat, or if they are heated to the same temperature, they will cool in different times, although exposed to the same degree of cold. These experiments prove, that different bodies have different capacities for heat, which capacities are expressed by the term *specific heat*.

The term specific heat then simply expresses the fact, that equal quantities of different bodies require unequal amounts of heat to elevate them to the same temperature; thus, if A takes four times as long to heat to the same temperature as B does, then its specific heat is 4 compared to B's, which is 1. Hence the *differences of times which different bodies exhibit when exposed simultaneously to the same heating or cooling influence, express their respective capacities for heat, or their specific caloric*.

Take a pint of mercury at  $100^{\circ}$  and a pint of water at  $40^{\circ}$ ,



and mix them, the resultant temperature is only  $60^{\circ}$ ; the mercury has lost  $40^{\circ}$ , and the water has gained only  $20^{\circ}$ . This is still more evident by taking equal weights, thus:

$$\left. \begin{array}{l} 1 \text{ lb. of mercury at } 162^{\circ} \\ 1 \text{ lb. of water at } 100^{\circ} \end{array} \right\} \text{ give a mixture at } 102^{\circ}.$$

The water has gained only  $2^{\circ}$ , while the mercury has lost  $60^{\circ}$ .

Again,

$$\left. \begin{array}{l} 1 \text{ lb. of water at } 162^{\circ} \\ 1 \text{ lb. of mercury at } 100^{\circ} \end{array} \right\} \text{ give a mixture at } 160^{\circ}.$$

The mercury has gained  $60^{\circ}$  while the water has lost only  $2^{\circ}$ . Water then has a greater specific caloric than mercury, the proportion between them being as 30 to 1.

To account for these phenomena, it was supposed that caloric existed under two conditions, viz.: 1st, *sensible*, and 2d, *insensible*; and those bodies having the greatest capacity for caloric render the most insensible, that is, they absorb more heat than other bodies, and vice versa. Again, if the volume is diminished, the capacity becomes less, and the heat is as it were squeezed out; in this way, by compressing air, tinder is fired by the sudden evolution of the insensible heat of the air. But this, which is only an hypothesis, fails, as in the burning of gunpowder, which expands a thousand times, yet no cold is produced.

#### LIQUEFACTION.

In liquids, the cohesive attraction is so far counteracted by the repulsive force, that the particles are free to move on each other. Now, as heat increases the repulsive force, it follows that solids may become fluid by the mere addition of heat. At a certain point then, all bodies cease to be solid,—

this is called the melting point; and the same bodies cease to be fluid at the same point; that is, the point of liquefaction and solidification are identical for the same body, but different for different bodies.

TABLE OF FREEZING AND MELTING POINTS.

Mercury melts at	.	.	.	.	.	—39° F.
Ice	.	.	.	.	.	+32
Potassium	.	.	.	.	.	136
Newton's alloy	.	.	.	.	.	212
Tin	.	.	.	.	.	442
Lead	.	.	.	.	.	612
Silver	.	.	.	.	.	1873
Gold	.	.	.	.	.	2016
Cast Iron	.	.	.	.	.	2786
&c., &c.						

A very important circumstance relative to liquefaction, is that a certain amount of heat is always absorbed before liquefaction commences; it is meant by this, that it disappears and becomes insensible to the thermometer. If a pound of water at 32° be mixed with a pound of water at 172°, the temperature of the mixture will be a mean between the two, that is, 102°. But if a pound of water at 172° be mixed with a pound of ice at 32°, the ice will dissolve, and on placing the thermometer in the mixture it will stand only at 32°; here the pound of water at 172° has actually lost 140° of heat, without raising the temperature of the ice, but causing its liquefaction.

Two flasks, one containing water at 33° and the other ice, were exposed to a temperature of 40°; in half an hour the water was at 40°, that is, it took 7° of heat, but the ice was not converted into water, and this elevated to 40°, until the expiration of twenty-one half hours; hence 147° of heat were absorbed, only 7° of which became sensible. The heat which

became insensible is called by Dr. Black *latent heat*; it is also called *heat of fluidity*.

TABLE OF LATENT HEAT OF SOME BODIES.

Water . . . .	140°	Zinc . . . .	493°
Sperm . . . .	145	Tin . . . .	500
Lead . . . .	162	Bismuth . . .	500
Beeswax . . .	175	&c., &c.	

The act of liquefaction then is a cooling influence, and it is on this principle that freezing mixtures are made. The degree of cold produced depends on the quantity of heat which disappears, and this is dependent on the quantity of solid matter liquefied, and on the rapidity of liquefaction.

The most common freezing mixture is equal parts of snow and salt; the former is liquefied in consequence of the great affinity which salt has for water, which then dissolves the salt; a thermometer placed in this mixture stands at zero. Frigorific mixtures with snow may be made to produce most intense cold; thus, ten parts of sea salt, five parts each of nitrate of potassa and muriate of ammonia, and twenty-four parts of snow, will sink the thermometer to  $-20^{\circ}$  from any temperature; and four parts of fused potassa with three parts of snow, will sink the thermometer from  $+32^{\circ}$  to  $-51^{\circ}$ .

Freezing mixtures may also be made without snow, by the rapid solution of salts; the latter must be perfectly dry; thus, eight parts by weight of sulphate of soda (Glauber's salts), and five parts by weight of chlorohydric acid (muriatic), will sink the thermometer from  $50^{\circ}$  to  $0^{\circ}$ , and equal weights of sulphate of soda and sulphuric acid (oil of vitriol), will depress it from  $50^{\circ}$  to  $3^{\circ}$ .

If liquefaction is a cooling process, condensation is a heating one. A very pretty illustration of this is the rise of temperature before a snow-storm; and if the air has previously been very cold, this will become remarkably sensible.

It is because the vapour or clouds while solidifying into snow give off their latent heat, thus rendering the surrounding atmosphere much warmer. This fact, it is said by Humboldt, renders the temperature of the Alps much warmer than it otherwise would be.

Ice liquefies at  $32^{\circ}$ , but the reverse is not always true, viz., that it freezes at  $32^{\circ}$ . If the water is kept perfectly quiet it can be reduced to  $21^{\circ}$  without freezing, because the shooting or polarization of the crystals is thus prevented. This can also be done with the crystalline salts, that is, their saturated solutions can be cooled down below the point of crystallization, but the moment the liquid is disturbed, it shoots into crystals and the temperature rises.

#### VAPORIZATION.

Vaporization is divided into *ebullition* and *evaporation*; the former is only rapid evaporation.

#### EBULLITION.

*Ebullition* is occasioned by the formation of bubbles of vapour within the liquid, which rise to the surface and there break; this occurs in different liquids at different temperatures, and the point at which it occurs is called the boiling point, which may vary, however, for the same liquid under different circumstances.

#### BOILING POINTS.

Ether . . . . .	96°	Oil of turpentine	314°
Sulphuret of carbon	116	Sulphuric acid	620
Alcohol . . . . .	172	Whale oil . . .	630
Water . . . . .	212	Mercury . . .	662
Nitric acid . . . .	248	&c., &c.	

The temperature of the liquid and the resulting vapour are always the same; that is, the temperature of steam is the same as that of the water from which it escapes; hence it is

inferred that the formation of vapour, like liquefaction, is attended with a loss of sensible heat, so that no matter how much heat you apply to the water, all above  $212^{\circ}$  is lost in the steam. The amount of this heat is obtained by condensing the steam in cold water, and observing the rise of temperature in the water which ensues.

## LATENT CALORIC OF VAPOURS.

Water . . . .	1000°	Alcohol of sp. gr. .835	457°
Ether . . . .	313	Oil of turpentine . .	184
Petroleum . . .	184	Nitric acid . . . .	550
Vinegar . . . .	870	Liquid ammonia . .	837

It is thus seen that water, if it did not evaporate and make heat latent, would actually become red hot.

There are circumstances which modify the boiling point, as follows :

1. The nature of the vessel and its surface.
2. Barometric pressure.
3. The depth of the liquid.
4. The freedom for the escape of vapour.

1. *The Nature of the Surface of the Vessel.*—Water will not boil so readily in a smooth glass vessel as in a metallic one, because there is an attraction between the surface of the glass and the water, which prevents a ready disengagement of it into vapour.

2. *Barometric Pressure.*—Diminish the pressure and you diminish the boiling point, and vice versa. On the surface of the earth there are elevations at which ether will not remain a liquid, as Mont Blanc, three miles above the level of the sea. Ether in a closed vessel may also be boiled by the mere application of cold, which, by condensing its vapour, relieves its surface of pressure, and thus permits it to boil.

The boiling point is lowered by ascending, and the height of mountains can thus be measured, remembering that for every 548 feet of ascent, the temperature at which water boils will be reduced one degree. To measure accurately in this way, a boiling point thermometer has been constructed, having a very large bulb and a very small tube; this will indicate the difference in the boiling point between the floor and a table.

The influence of the atmosphere on the boiling point is well shown by removing its pressure altogether. It has been discovered that liquids boil in vacuo at a temperature  $140^{\circ}$  lower than under the pressure of the air or an equal one. Thus water boils in vacuo at  $72^{\circ}$ , alcohol at  $36^{\circ}$ , and ether at  $-44^{\circ}$  F.

When water is converted into vapour at  $212^{\circ}$ , with the thermometer at  $60^{\circ}$  F., and the barometer at 30 inches at the level of the sea, the tension of the vapour produced is just equal to that of the air, that is, fifteen pounds to the square inch; this is called *low steam*. Again, if water is boiled in a vessel which prevents the escape of the vapour, its tension or elastic force is increased, and it is then called *high steam*. The tension of the vapour of water can be ascertained by experiment; thus, a strong metallic instrument, with a column of mercury attached and a thermometer, is partially filled with water, and this is then boiled; as the steam generated has no means of escaping, it goes on accumulating in the vessel, acquiring greater tension every moment, which tension is measured by the column of mercury; when this stands at 30 inches, the tension is then equal to two atmospheres, and the thermometer is found to stand at  $250^{\circ}$ , that is, an additional pressure of fifteen pounds to the square inch elevates the boiling point  $38^{\circ}$ .



TABLE OF TENSION OF VAPOURS ABOVE 212°.

1 atmosphere, at	.	.	.	.	.	212°
2	"	.	.	.	.	250
3	"	.	.	.	.	275
4	"	.	.	.	.	294
5	"	.	.	.	.	320
8	"	.	.	.	.	342
12	"	.	.	.	.	374
16	"	.	.	.	.	398
20	"	.	.	.	.	418
50	"	.	.	.	.	510

In the above table most of the higher numbers have been calculated, because it will be evident that no vessel ever constructed could bear a pressure of 50 atmospheres, or 750 pounds to every square inch of surface.

The steam of steam engines is high steam, having a pressure generally equal to six atmospheres; this steam, in a high pressure engine, is communicated before and behind a piston, by means of sliding valves, causing the piston to move backwards and forwards.

Low pressure engines differ from high pressure, by creating a vacuum before and behind the piston by means of a condenser, so that the piston is driven into a vacuum, instead of against the pressure of the atmosphere.

3. *Depth of Column of Liquid.*—Suppose a vessel 34 feet high filled with water; the pressure exerted by that column of water will be 15 pounds on every square inch, while the atmosphere also presses on its surface with a force equal to 15 pounds on every square inch; hence the whole pressure on the bottom of the vessel will be 30 pounds to the square inch, and it will therefore require a temperature of 250° before it will boil at the bottom.

4. *Freedom for the Escape of Vapour.*—It is very obvious that if the steam is not allowed to escape, it will go on ex-

eriting increased pressure on the surface of the fluid, its tension being inversely as its bulk; therefore the boiling point will be elevated in proportion as the pressure is increased.

#### EVAPORATION.

Water is evaporating at all temperatures; this is readily proved by introducing water in the Torricellian vacuum, when the mercury will be observed to descend; the amount of fall depending on the temperature of the water introduced. Thus, add a small portion of water at  $65^{\circ}$  over the surface of the mercury, and its vapour will fill the vacuum, causing a fall in the mercury of  $\frac{6}{10}$  of an inch. Below we give a table of the *elasticity of vapours*, from  $32^{\circ}$  to  $212^{\circ}$ .

At $32^{\circ}$ . . . . .	·200	At $90^{\circ}$ . . . . .	1·86
40 . . . . .	·263	100 . . . . .	1·86
50 . . . . .	·375	120 . . . . .	3·33
55 . . . . .	·443	140 . . . . .	5·74
60 . . . . .	·524	160 . . . . .	9·46
65 . . . . .	·616	180 . . . . .	15·15
70 . . . . .	·721	200 . . . . .	23·64
80 . . . . .	1·000	212 . . . . .	30·

The first column in the above table represents the degrees of heat, and the second column represents the tension in inches of mercury; we thus see that a temperature of  $100^{\circ}$  is only equal to 1·86 inches, which is equivalent to less than a pound to the square inch, while  $180^{\circ}$  is equal to 15·15 inches, or  $7\frac{1}{2}$  pounds, and  $212^{\circ}$  is equal to 30 inches or 15 pounds.

Evaporation, like ebullition, renders a vast amount of sensible heat insensible. Thus the latent heat of steam at  $212^{\circ}$  is nearly 1000, and if this be condensed to  $32^{\circ}$  F.,  $180^{\circ}$  of sensible and 1000° of insensible or latent heat are given off;



and in all cases  $1180^{\circ}$  altogether are given off when the vapour of water is condensed at  $32^{\circ}$ , hence the latent heat of the vapour is found by subtracting the sensible heat from the constant quantity,  $1180^{\circ}$ . Now take the vapour of water at  $100^{\circ}$ , and by condensing it at  $32^{\circ}$ , it is found that  $100^{\circ} - 32^{\circ} = 68^{\circ}$  of sensible heat are given off, while at the same time there are  $1112^{\circ}$  of insensible heat; these two making the constant number,  $1180^{\circ}$ . If such a vast amount of sensible heat becomes insensible during evaporation, it follows, that intense cold may by these means be produced. Thus place a dish of water in an exhausted receiver, the floor of which is covered with oil of vitriol, to absorb the vapour of water as fast as it is formed, evaporation will take place so rapidly that the water in the dish will be frozen.

Evaporation, like ebullition, is modified by many causes, as follows:

1. *The Nature of the Liquid*, some evaporating more rapidly than others, as ether than water.

2. *The Extent of Surface*.—If the same amount of liquid is placed in a tall vessel, and in a broad shallow one, and both exposed to the same influences, it will be found that the liquid in the shallow vessel will disappear the sooner.

3. *The Greater or Less Dryness of the Air*.—Gases or vapours are to each other, according to the law of diffusibility, as *vacua*; now when the air is perfectly dry it will of course hold much more vapour than if it already contained some.

4. *The State of Motion or Rest of the Air*.—The evaporation is greater while the air is in motion, because the air on the surface of the water is moved away as fast or faster than it becomes saturated with moisture, and then presents a new surface of dry air.

5. *The Temperature*.—The ultimate quantity of vapour in

the air depends always on the temperature. The quantity of vapour with the same space will always be the same whether there is air present or not, other circumstances being alike; that is, a receiver will hold the same amount of vapour whether it be exhausted or not; but when the *temperature* is increased, the amount of vapour is increased also. The air always contains more or less vapour, and if, as has been said, the temperature be increased, then the vapour will be also; but if the temperature be reduced, some of it will be immediately removed by condensation, and rain or hail, or snow, or dew, or mists, will result.

The temperature at which moisture is deposited from space is called the dew point, and this point must always vary with the temperature. Thus in a warm dry day, ice will smoke, that is, condense vapour around it; but if the day be cold, no such result will take place. Instruments for measuring the dew point are called hygrometers; the simplest of these is a silver cup containing water, which is cooled down until moisture is deposited outside, and then the temperature noticed by a thermometer placed in the cup. Hair and many other things are also hygrometric.

There is a condition of liquids not yet mentioned, called the *spheroidal condition*.

If water is placed on a red hot, smooth, metallic surface, instead of disappearing in the form of vapour, the water will play over its surface like a lens or spheroid, and continue to do so until the temperature of the surface is reduced to  $212^{\circ}$ , when it will suddenly disappear in the form of vapour. Alcohol, ether, and many other liquids, assume the same condition.

There is no doubt but that this is very frequently the case in steam boilers; they are heated red hot; the water in them assumes a spheroidal condition, and of course no steam is generated or indicated; the engineer lets in water, and the

boiler is suddenly cooled to a proper degree, when the whole of the spheroidal water bursts into steam with immense violence, and shatters everything within its influence.

#### DISTRIBUTION OF CALORIC.

Heat is distributed by conduction, by convection, and by radiation.

*Conduction.*—Hold a rod of metal in a flame, and the heat will very soon be communicated from one end to the other. A rough experiment of the different conducting powers of different substances, may be made by placing several rods of different kinds in a frame, so that their lower ends will dip in hot water, and then place on the top bits of phosphorus, noticing the times in which they take fire by conduction of heat from the water.

TABLE OF CONDUCTIBILITIES.

Gold . . . . .	1000	Tin . . . . .	304
Silver . . . . .	973	Lead . . . . .	180
Copper . . . . .	898	Marble . . . . .	23
Iron . . . . .	374	Porcelain . . . . .	12
Zinc . . . . .	363	Clay . . . . .	11

It will be seen by the table that metals are the best conductors, then stones, &c. Liquids and gases are very bad conductors, the latter almost inappreciable.

*Convection.*—By convection is meant the carrying of heat by means of the particles of bodies free to move, as a liquid or gas. In boiling water heat is communicated in this way, by a current being established by the hotter particles rising from the bottom and descending as they cool. Water, and indeed all liquids, must be heated by convection, although

liquids are to a very slight extent, conductors. Dr. Murray proved this by using a vessel of ice, and pouring in water; he then heated the surface of the water, and a thermometer placed near the bottom indicated a rise of a few degrees.

When water at  $33^{\circ}$  is heated on the surface, the particles become heavier and sink, until the temperature reaches  $40^{\circ}$ , and heat is thus conveyed below.

Gases become heated only by convection. The more porous substances are bad conductors, because there is a great deal of air or gas in them; hence such substances are the warmest clothing, as furs, wool, &c., and for the same reason loose clothes are the warmest, because they interpose a stratum of air between.

*Radiation.*—Heat passes in all directions from a hot body, and in right lines like the radii of a circle. The rays thus distributed pass as freely through the air as they would through a perfect vacuum, and vice versa. When they fall on the surface of a body, they may be disposed of in three ways, viz., be *reflected*, *transmitted*, or *absorbed*. In the first and second cases, the temperature of the body on which the rays fall is unaffected, in the third case it is increased.

Different bodies radiate heat differently; this was demonstrated by Leslie: he used a cube having sides constructed of different materials, as paper, glass, &c., and the different radiating powers he measured by an instrument called the *differential thermometer*. This consists of a glass tube, bent in the form of the letter U, having a bulb at each end; enclosed is coloured sulphuric acid. It is an air thermometer, and will indicate the slightest

differences in temperature.

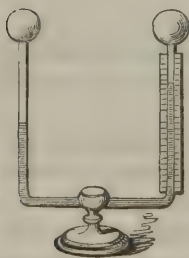


TABLE OF RADIATION.

Lampblack . . .	100	Polished iron . . .	15
Writing paper . .	98	Tin	
Sealing wax . . .	95	Gold	} . 12
Crown glass . . .	90	Silver	
Red lead . . . .	80	Copper	

Leslie and many others supposed that colour had great influence on radiation, and that dark bodies radiated most; but this is not so, for by looking at the table it will be seen that writing paper, which is white, is 98, compared to lamp-black, which is only 100. Radiation depends more on the surface than the nature of the radiating body; a rough surface giving off more than a smooth one, because it presents a greater number of points from which the heat may escape.

*Reflection of Heat.*—When heat impinges on a smooth opaque surface, it is thrown back in a straight line—this is called reflection: the law of reflection is, that the angle of incidence is equal to the angle of reflection. The incident angle is the one included between the incident ray and a line drawn perpendicularly to the reflecting body, and the angle of reflection is the one found on the other side of that line. The brightest surfaces are the best reflectors of heat.

*Absorption of Heat.*—Every increase in temperature from radiant heat, is due to absorption, and the number of absorbed rays is supplemental to the reflected ones. Absorption is directly as the radiation, and therefore those bodies which radiate most, absorb the most.

*Transmission of Heat.*—Radiant heat passes through a vacuum with perfect freedom. The air, gases, &c., present also very little obstacle to its transmission, but transparent bodies of a denser kind interfere very much with its passage. Simple heat is now only referred to, that is, heat unconnected with light. The property which solids have of transmitting heat is called transcalency; and rock salt possesses this property in the highest degree.

*Theory of Radiation.*—The equilibrium of temperature is maintained by radiation, and all bodies are radiating heat at all times; but a hot body is giving off more heat than it receives, and vice versa.

This serves us to account for the formation of dew at night. It is because the earth radiates in a clear mild night more heat than it receives from the surrounding air, and hence its temperature becomes reduced lower than the air, and dew is deposited; but if there are clouds, these will return the heat as rapidly to the earth as it gives it off, and no dew falls. The same principle will serve to explain why this dew may be frozen, although the thermometer stand at  $40^{\circ}$ ; it is because the water gives off heat to the surrounding air, which does not return it so rapidly, and its temperature is thus reduced by its own radiation to  $32^{\circ}$ , although the air is  $40^{\circ}$ .

*Sources of Heat.*—The sun is the great source of heat; its rays strike the earth, which being a non-conductor becomes much heated, and the more vertically these rays strike the earth the hotter it becomes. The comparative coolness of our middle latitudes is due to the obliquity with which these rays strike us, thus allowing most of them to be reflected. As air is only heated by its being in contact with the earth, and not by the transmission of the sun's rays through it, it follows that the higher we ascend the colder it will become. At different altitudes above the surface, the thermometer varies, and the variation is true for the same latitudes, height being the same; as a general rule, however, it may be stated, that the thermometer falls one degree for every 548 feet of ascent. The line of perpetual snow or frost must vary then with the latitude, that is, the highest point is at the equator and the lowest at the poles.

At the coast of Norway it is . . . . .	2340 feet.
At the coast of Iceland it is . . . . .	3040 “
On the Alps . . . . .	8801 “
On Etna . . . . .	9441 “
In Mexico and on the Himalayas . . . . .	15000 “



A line drawn through all these points is called the *isothermal line*.

The earth has other sources of heat independent of the sun. There is a point below the surface of the earth where the temperature for the same latitude remains the same throughout the year. This is called the *isogeothermal line*. For our latitude the temperature at 45 feet below the surface is 52° F., and all our flush springs preserve the same temperature throughout the year. But water brought up from beyond this depth has an increased temperature, and it increases with the descent. The sun's influence does not extend beyond from 40 feet to 100 feet, hence there must be something else heating the water beyond this depth.

This cause is by the geologist said to be the internal condition of the earth, viz., that it is a mass of fused and melted matter, and we are residing on a mere crust. The arguments in proof of this state of things are very numerous; thus the warm springs are due to the tilting up of strata, the rocks of which, if in the ordinary horizontal condition, would be several thousand feet below the surface, as in the warm springs of Virginia. Artesian wells, the undulatory form of the earth's surface, the existence of coal in Greenland, the oblate spheroidal shape of the earth, volcanic discharges, &c., &c., are all arguments in proof of the theory.

For every 60 or 70 feet below the *isogeothermal line*, there is a rise of 1°, and it can thus be calculated that at 30 miles below the surface all rocks and every other material must be fused. Our planet is in fact only a vast furnace, while the volcanoes are its chimneys.

There are other sources of heat besides those mentioned as *combustion, electricity, chemical action, vital action, and mechanical action*.

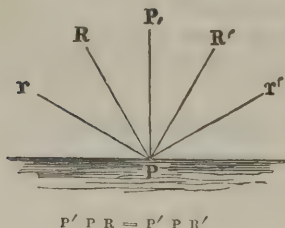
## SECTION III.

## LIGHT.

Two theories have been proposed to account for the phenomena of light. The first (Newton's) assumes light to be a material emanation from a luminous body, of inconceivably minute particles, which travel in straight lines with immense velocity. The second (Des Cartes') asserts that it is an ethereal medium pervading all space and all bodies, and that the sensation of light is produced by undulations being excited in it by means of a luminous body. The latter theory is supposed to apply best to all the conditions which light can assume.

Light is emitted from every point of a luminous body, like the radii of a circle; it proceeds in straight lines with a velocity of 195,000 miles in a second of time, and when it falls on any body it is either *reflected*, *refracted*, or *absorbed*.

*Reflection.*—All bodies reflect light, for if a body is seen at all, it must be only by means of reflected light, else no knowledge of it could be obtained; and the distinctness with which bodies are seen, depends on the number of rays reflected.



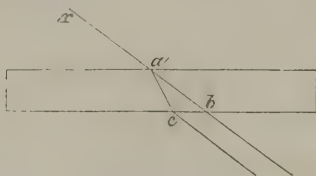
The general laws in the disposition of reflected light are, *that the incident and reflected rays always lie in the same plane, which plane is perpendicular to the reflecting surface; and that the angle of reflection is always equal to the angle of incidence.*

These laws apply equally to concave and convex surfaces, which are viewed as polygons, each point where a ray strikes being considered as a very small plane.

The greater the angle of incidence, that is, the more inclined the ray, the greater will be the amount of light reflected, except in white bodies, as snow, which reflect most when the angle is least.

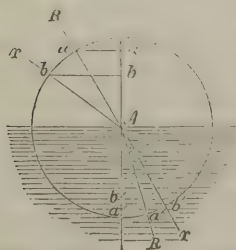
*Refraction.*—The spaces through which light comes are called media, as air, glass, water, &c. Some of these permit bodies to be seen through them, and are called transparent, while others only allow the light to come through diffusively, and are called translucent. When light passes through a medium of the same density throughout, it proceeds in straight lines; but when it passes from one medium into another of different density, or from one part of the same medium into another of different density, it is *broken* or *refracted* at the surface or junction of the two media, except when the ray of light is perpendicular to that plane.

The ray  $r a$ , impinging on the plate of glass at  $a$ , instead of going on in the direction  $a b$ , is bent at the point  $a$ , in the direction of  $a c$ , until it reaches the other surface  $c$ , when it is again bent, and proceeds in a direction parallel to  $r a$ .



The laws regulating the direction of rays through refracting media are, that *when the ray of light proceeds from a rarer into a denser medium, it is refracted to a line perpendicular to its surface, and when it goes from a denser into a rarer, it is refracted from the same line, except the light impinges vertically on the refracting medium, in which case it passes through without refraction.*

Some bodies refract more than others, and in general the denser the substance the greater is the deviation. The direction of the incident and refracted ray is always in a plane perpendicular to the surface, and the indices of the refracting powers of media are constructed in reference to sines.



Thus in the figure we suppose that the sine of the angle of refraction is to the sine of the angle of incidence, as 1 to 2; then each ray must conform itself to this law; as the sine of  $a A a$  is to  $a' a'$ , the sine of  $a' A a'$  as 2 to 1, and  $b b$  is to  $b' b'$  as 2 to 1.

The sines of the substances below are constructed in reference to the angle of refraction being 1. The numbers are called indices of refraction, and indicate the refracting power, that is, they are the sine of the angle of incidence compared to that of refraction, which is taken as 1.

Substances.	Indices of refraction.
Ice . . . . .	1.30
Water . . . . .	1.33
Fluor spar . . . . .	1.40
Plate glass . . . . .	1.54
Rock crystal . . . . .	1.60
Oil of cassia . . . . .	1.61
Sulphuret of carbon . . . . .	1.70
Flint glass . . . . .	1.84
Phosphorus . . . . .	2.20
Diamond . . . . .	2.43
Chromate of lead . . . . .	3.00

It was observed by Newton, while experimenting on refraction, that many of those substances possessing great refractive power, were combustible, and he therefore inferred that

the diamond, one of the most refrangible bodies known, would some time or other be proved to be combustible; this result actually happened fifty years after this prediction. Water, which is a very good refracting medium, contains the very type of combustible bodies, viz., hydrogen. The general law of refraction is as has been stated; the denser the liquid the greater the refracting power, but the exceptions are very numerous; thus gases refract most when rarest, and essential oils, which are lighter than water, refract more than it does.

In studying the transmission of light through curved media, the same rule applies as in reflection by curved mirrors. Convex lenses collect rays, bringing them to a point called the focus, while concave lenses disperse them.

A ray of common light made to pass through certain kinds of crystals, undergoes a very remarkable change. It becomes divided into two, one of which is refracted in the ordinary way, while the other takes an extraordinary direction. This effect is called *double refraction*; it is seen in the Iceland spar, by placing it on a piece of paper, having a spot or line on it, when the figure will be seen doubled.

If a ray of light impinges on a plate of glass at an angle of  $56^{\circ} 45'$ , that portion of the ray which is reflected, is found to have acquired new properties, for on throwing it at the same angle on another plate of glass it ceases to be reflected in two particular positions. This is called *polarized light*. It is also found that the portion of the ray which passes through the first plate, has this peculiar condition, but in an opposite state to that polarized by reflection, that is, the transmitted ray is reflected by the second or analyzing plate, when the reflected ray is absorbed, and vice versa.

#### SOLAR SPECTRUM.

When light is made to pass through a medium the sur-

faces of which meet at an angle, forming a prism, there is a new and peculiar arrangement. The light is broken up into seven colours, viz.: red, orange, yellow, green, blue, indigo, and violet. When solar light is employed, these colours are very brilliant, and are spread into an oblong space called the *Solar Spectrum*, the upper part of which image or spectrum is violet, while the lowest is red. White light then is composed of seven primitive colours, the rays of which possess different refrangibilities for the same medium, the violet being the most, and the red the least refrangible.

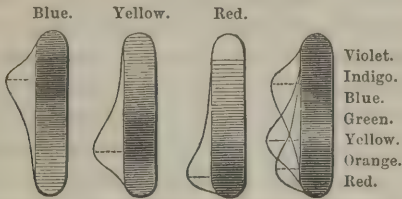
It is due to this decomposition that every body possesses colour; there would be nothing but white and black, and everything in the universe would present the most sombre appearance, were it not "that light, the robe of day, is a woof twisted with many colours."

These seven colours may be reconstituted by a lens, which, concentrating them all into one focus, produces a spot of pure white light. By passing these colours in the order in which they occur very rapidly before the eye, the sum of the impressions made on the eye will be white light. Thus light moves 195,000 miles in a second,—the human eye retains an impression on the retina  $\frac{1}{8}$  of a second; now take a disc and paint the seven primary colours on it in succession, and make it revolve rapidly before the eye by a string, then the whole impression produced is that of white light; just as a musical note is a succession of rapid noises, so rapid that the intervals cannot be distinguished, and the whole impression is that of a sweet tone.

The ray of light has been decomposed into seven primary colours, but it is now proved that four of these colours are compound ones, viz., orange, green, indigo, and violet; and that there are in reality only three primary colours, red, yellow, and blue, and that these constitute all the others. There is no doubt of this being the true state of the case, as by a



combination of red and yellow we get orange; yellow and blue give green, &c. Each colour extends over the whole spectrum, but has its greatest intensity at one part (indicated by the height of the curve in the diagram).



These rays have undergone different degrees of refraction; the red is less bent than the yellow, and the yellow than the blue. Green is the middle colour of the spectrum, and has the medium of refrangibility and the greatest illuminating power.

A body is seen, as has been said, only by the light it reflects; that is, a red body is seen, although white light impinges on it, because red rays only are reflected. White bodies reflect all the rays, and have therefore the most colour, although it is denied that white is a colour. Black bodies absorb all the rays and reflect none; at least this is true in theory, but they always reflect sufficiently for us to see them; if they did not do this, black would be no colour. Every ray of light, no matter what its colour, possesses all the other colours, for the reasons shown. If this were not so, the following result would not happen, viz., when a beam of green light is thrown on a body which is red (when viewed by white light), it will still appear red, and can be seen. Now this can only happen by the reflection of red rays, for if these were not reflected, it could not be seen at all; hence then every colour possesses the elements of all the other colours.

*Calorific Rays of the Solar Spectrum.*—The spectrum, besides the property of giving colour, has also a heating power, and this property varies in intensity in different parts of the spectrum.

When a flint glass prism is used, the point of maximum heat is beyond the red about half an inch, diminishing till it reaches the violet; but with a prism of crown glass, the red is the hottest, while with a prism composed of glass externally and water internally, yellow is the hottest part.

*Chemical Rays of the Solar Spectrum.*—Light is necessary to life; all changes of colour, and many others in the natural world, are due to its influence; in fact, total darkness would be total death.

Chlorine and hydrogen combine under the influence of light; the haloid salts of silver are darkened by it also. Now it is neither the calorific nor colorific rays that produce these effects, but they are due to certain invisible rays that accompany these, which are found most abundantly in and beyond the violet part of the spectrum. These are called the chemical rays, and they are the most refrangible part of the spectrum.

These rays have been successfully used within the last few years for the purpose of drawing, and the science of *photogenics*, as it is called, has become a very prominent one.

The *daguerreotype* is a good instance of the effects of the sun's rays. A silver plate is exposed to the vapours of iodine, and an iodide of silver is thus formed on its surface; this is then placed in a camera obscura, being careful in the transfer not to expose the plate to light; of course now any object before the lens of the camera will make an impression on the plate, and where the light is most intense, there the iodide of silver will be most removed from the plate; it is now exposed to the vapour of mercury, which brings out the picture by rising and attaching itself to the surface where the iodide

is removed, thus forming the lights, while the dark polish of the silver constitutes the shades of the picture. It is now washed with a solution of hyposulphite of soda, in which the iodide of silver is soluble, and is thus removed. There is nothing now on the daguerreotype plate but minute globules of mercury, which thus form the picture, relieved by the dark polish of the plate.

A *talbotype* is on precisely the same principle, only that paper is used instead of a silver plate. This paper is prepared with an iodide or bromide of silver; the light proceeding from any object removes the salt and gives a negative picture, which must be then used to obtain a positive one.

A *hyalotype* is a transfer of a picture or object on glass having a salt of silver and some organic body present on its surface.

*Absorption of Light.*—Solar light possesses the property of exciting heat as well as light. This effect takes place only when the ray is absorbed, the temperature of transparent substances through which it passes, or of opaque ones that reflect it, remaining unchanged. Hence the lens remains cool while there is an intense heat at its focus. The intense cold of the higher strata of air is also due to this cause, because the sun's rays pass on through unabsorbed, and its lower strata only become warm by contact with the earth.

The absorption of light is much influenced by the nature of the surface on which it falls; and it is a fact that those substances which absorb radiant heat most powerfully are, as a general rule, the best absorbers of light, although there are very many exceptions. Colour has a very great influence over the absorption of light; thus dark-coloured substances acquire a greater temperature in the same time than light ones, proving that they absorb more light, and of course more heat. Hence it is that light-coloured clothes are the coolest in summer.

## SECTION IV.

## ELECTRICITY.

THE word electricity is derived from the Greek word *ηλεκτρον*, amber, because it was originally excited on it.

When certain substances, as amber, sealing-wax, sulphur, and glass, are rubbed with a dry cloth, they will, when held near light bodies, as gold leaf, pith-balls, &c., attract them; or if the bodies rubbed be freely suspended, they will move towards contiguous bodies. The bodies rubbed are said to be electrified. If we now present an electrified body to a pith-ball suspended by a silk thread, it will at first be attracted and then repelled; and if two pith-balls be brought in a state of repulsion to the electrified body, they will repel each other. But if one be in its natural condition, and the other in a state of repulsion, they will attract each other; or if one has been excited by glass and the other by resin, they will be mutually attracted.

Hence the law, *similarly electrified bodies repel each other, and dissimilarly electrified bodies attract each other*. The instruments used are electroscopes or electrometers; they only indicate the presence of electricity.

To distinguish the two kinds of excitement from each other, terms are used which, although arbitrary, must be understood by the student as merely expressing the facts, without reference to theory. The electricity manifested on glass is called positive or vitreous, and that on resinous bodies negative or resinous. It will be remembered that the rubber is always in a state opposite to the thing rubbed, for it is impossible to develop the one without the other.

To account for these phenomena two theories have been proposed.

*Theory of Two Fluids.*—It was supposed by the French that there were two kinds of electricity, that is, two distinct fluids, and that these were accumulated on all substances, and possessed of the most perfect subtlety and fluidity; that one was vitreous because developed on glass, and the other resinous because developed on sealing-wax; that these mutually attracted and formed the neutral vitreo-resinous electricity, and that vitreous would repel vitreous, and resinous repel resinous, that is, they were *ideo-repulsive*; and lastly, that when these two neutralized each other there was an equilibrium, which equilibrium was destroyed by disturbing causes, as friction, &c., giving rise to electric excitation and all its phenomena.

*Theory of One Fluid.*—Opposed to the last theory is Dr. Franklin's, or that of a single fluid. This supposes only one kind of electricity, of which the earth is the great reservoir; that all matter has a certain amount, which is liable at any moment to be disturbed by friction, change of temperature, and other causes, just in the same manner as a heated body disturbs the equilibrium of temperature in surrounding bodies; that when a body has an excess it is *positive* (which is the same as vitreous), and when a body is possessed of too little it is *negative* (corresponding to resinous); that there is always a tendency to an equilibrium, by the fluid radiating, as it were, from the positive to the negative; and lastly, that these states repel each other, that is, a plus state repels a plus state, and a negative repels a negative state.

Very many objections may be advanced against both of these theories, and therefore no one scarcely commits himself to either, resting satisfied with the facts themselves.

All bodies that indicate electric excitation are called *electrics*; those that do not, *non-electrics*. The latter convey

away the electricity as rapidly as it accumulates, and are hence called conductors, while the former are called non-conductors. Conductors may be made to exhibit electric excitation, by being placed under such conditions that the fluid cannot escape, viz., by being insulated on non-conductors, as glass, &c.

TABLE OF CONDUCTORS AND INSULATORS.

Conductors.	Insulators.
Metals,	Spermaceti,
Charcoal,	Glass,
Fused salts,	Sulphur,
Strong acids,	Fixed oils,
Alkaline solutions,	Spirits turpentine,
Water,	Resins,
Alcohol,	Ice,
Damp air,	Diamond,
Vegetable and animal bodies.	Shell lac,
	Dry gases.

## CAUSES OF ELECTRIC EXCITATION.

*Friction.*—This, which, as has been already mentioned, is the most usual method of obtaining electricity, is the principle of the electrical machine, which is only a rubber and a thing rubbed. It consists of a plate or cylinder of glass, usually covered with silk, revolving on its axis, in contact with a rubber, and a metallic body, called the *prime conductor*, to convey away the electricity as fast as developed; this and all other parts of the instrument are insulated, to prevent the electricity from being conveyed away to the earth. In this way it is evident that the prime conductor can have a large amount of electricity accumulated on its surface.

*Change of Temperature.*—This is a very frequent source of electricity, and may be demonstrated by heating metallic



rods to different temperatures at their extremities. The study of it is called thermo-electricity.

*Chemical Action.*—This will be evident when we treat of galvanism.

*Proximity to an Electrified Body, or Induction.*—Electricity is a force passing through space, at appreciable distances, although non-conducting bodies may be interposed, and this is a direct consequence of the attractive and repulsive powers ascribed to electric fluids. If we place an insulated conductor with its end towards the prime conductor of an electrical machine, the end which is toward the conductor will assume a negative condition, while its other end will be positive, and any series of conductors will assume the same condition. This is called *induction*, and it will take place although plates of glass are interposed; it is a key to all the phenomena of electricity.

An electrified body attracts light objects near it, as pith-balls, because it induces in them a state opposite to itself, and they are therefore attracted. On moving the hand towards the prime conductor of an excited machine, a spark is elicited, because the hand is made negative by induction, and the spark then restores the equilibrium. A cloud charged with electricity, coming over any point on the earth, induces an opposite state, and an electric spark, or lightning, is the result.

Leyden jars are on this same principle. They are glass bottles with wide mouths, coated internally and externally with tin foil, except to within three or four inches of the summit; the mouth is closed by a cork, through which a metallic conductor is conveyed to the inside coating. Now on placing the metallic conductor of the jar in contact with the prime conductor of the machine, the inside of the jar, it is obvious, will become charged with positive electricity, while the outside surface will be negative, by means of the polarization of the molecules of glass between the surfaces, or

in other words by induction. If we now establish a communication between the internal and external coats, a spark will be elicited and the equilibrium restored. The coating of tin foil only serves as a conductor to spread the electricity over the surfaces of the glass, which would otherwise be attached in points, on account of its being an insulator.

Many Leyden jars can be arranged to constitute a battery, to be discharged at once, thus exhibiting on a small scale the effects of lightning.

Electric excitation is due, as we have said, to polarization, that is, every particle is positive on one side and negative on the other ; but although every particle is thus excited, there is only a manifestation of electricity at the surface.

A perfect sphere has an equal distribution all over its surface, but if it is elongated, an accumulation takes place at its ends, and if elongated still farther into points, the accumulation becomes very great at the extremities. This is due to the repulsion of the fluid, and as it is held on the surface probably by the attraction of that surface only, it follows that electricity will flow off very rapidly from points, which present only a small surface ; hence it is that there is much difficulty in getting a shock from a point. But on a large surface it must be accumulated in very large quantities before a discharge will be permitted, and when it does take place a spark is observed, due then entirely to the intensity. We must contemplate then all excited bodies as being in a polar state, and this condition pervading the whole mass, although manifestation takes place at the surface only.

#### ELECTROSCOPES.

It is necessary, in experimenting on electricity, to know when a substance is electrified, along with its intensity, &c. The pith-balls suspended and repelling each other when

electrified, are examples of these instruments. The gold leaf electrometer is also used. The quadrant measures the intensity by the divergence of a pith-ball from a perpendicular. The balance electrometer measures the amount of excitation by the weights lifted by the attractive forces.

## GALVANISM.

Galvanism was discovered accidentally by Galvani, in 1790, by observing that when a scalpel was in contact with the sciatic or crural nerves of a frog, and the scalpel was touched by the chain of an electrical machine, muscular contractions were produced.

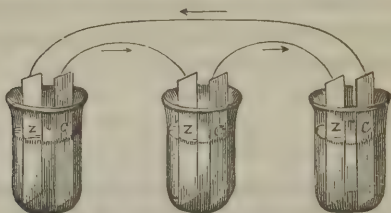
It was inferred from this, that electricity was the cause of all muscular movements. This, however, was denied by Volta, who contended that the muscle was only an electroscope, indicating by its movements the presence of electricity.

Galvanic, and the electricity of the common machine, are identical; the latter being insulated, has great intensity, but the quantity is small, yet having powerful attractive and repulsive energies. In galvanism, however, there is a very large quantity developed, but it never has much tension, and it produces its peculiar effects while flowing along conductors in a continuous current, the quantity being so great that we never consult the condition of insulation.

*Voltaic Circles.*—When a plate of zinc and one of copper are made to touch each other, electricity is excited by the contact, but in very small quantities; if the plates be put in a vessel of dilute sulphuric acid, and their edges placed in contact above or connected by means of wires, a current of electricity will be established, and hydrogen gas will escape at the copper plate, while the zinc one will become oxidized.

The current sets out from the most to the least oxidable metal in the water, and from the latter to the former out of

the water; as in the diagram from the zinc to the copper in the liquid, and from the copper to the zinc out of it.



But if ammonia be used in the copper-zinc battery, instead of acidulated water, the current will be reversed, because the copper is more readily acted on by the ammonia than the zinc is.

A chemical operation is necessary to the production of galvanism, and it matters not what the metals are, so that one is more readily acted on than the other.

A simple voltaic circle may be formed of one metal and two liquids, by a stronger chemical action being induced on one side of the metallic plate than on the other.

A great many voltaic circles connected constitutes a battery, of which there are very many modifications, it only being necessary to have two perfect and one imperfect conductor of electricity for each simple cell; the conductors are the metals, and the imperfect one, the water or aqueous solution. In every arrangement, it will be found that the metal most attacked is positive with regard to the other, that is, the current sets from it to the other through the liquid inside, and around to it outside. The great battery of Davy, by means of which he made his celebrated discoveries of the compound nature of the alkalies, consisted of 2000 plates.

In galvanism we distinguish between quantity and tension. As a general rule, the former is very great, while the latter is very small. The quantity depends on the surface, but the

tension depends on the number of plates, each plate added giving, as it were, additional impetus or tension.

The energy of a voltaic current is measured by the deflection of the magnetic needle from its meridian; the needle is actually a galvanometer, assuming a position east and west, and capable of measuring, not only the energy of the current, which it does by the amount of deflection, but also its direction.

*Constant Batteries.*—It was found by experience that the common zinc and copper battery, by being used, diminished very much in its action, so that in a short time no electricity was manifested at all. To prevent this, platinum, plumbago, and other arrangements have been introduced, for the purpose of rendering the action of the batteries constant.

In a zinc and copper battery, the following phenomena take place when the circle is closed :—The sulphuric acid acts on the zinc and disposes it to decompose the water, which it does, its oxygen uniting with the zinc, forming the oxide of zinc, and this again with the acid, forming sulphate of the oxide of zinc; but the hydrogen is being evolved at the copper plate, and this hydrogen, which is in its nascent or new-born condition, and has then its greatest energy, decomposes the oxide of zinc, by taking its oxygen, and the salt is thus destroyed, while the zinc is then deposited in a metallic form on the surface of the copper, eventually becoming a suboxide of zinc, from the absorption of oxygen from the air or water; a zinc-zinc battery is thus had instead of a copper-zinc one, and one of the conditions for a circle is lost, viz., that one metal be more readily oxidable than the other. If now nitric acid be added to the sulphuric acid solution in the zinc and copper battery, the nitric acid will be decomposed and render up its oxygen to the hydrogen as rapidly as it is formed, and thus re-form water, rendering the action of the battery more constant.

But a still better form of a constant battery is the follow-



ing (seen in the diagram), which may consist of any number of cells, each of which is composed of a glass vessel, holding a zinc cylinder; within the zinc is a porous porcelain cylinder, but not so large as to fill up the cavity of the zinc one; and, lastly, the porous porcelain cylinder holds a slip of platinum.



A solution of sulphuric acid is now placed between the zinc and porcelain, and a weak solution of nitric acid poured into the latter, thus surrounding the platinum slip. As soon as the circle is closed by the junction of the wires, one of which is attached to the zinc and the other to the platinum, a current sets in from the zinc to the platinum; a sulphate of zinc is formed, which is prevented from going through by means of the porous partition, and a deposition of zinc thus prevented. Again, as bubbles of hydrogen often collect on the surface of the other plate, whether copper or platinum, and thus prevent the action of the battery, nitric acid is added, which by its decomposition, and consequent yielding up of oxygen, prevents such an occurrence, by this oxygen uniting to the hydrogen, and thus re-forming water.

Other methods have been introduced to render batteries constant, but the principle of all will be understood from the above description of one.

It has been already said, that the current is dependent on the action and the surface, but there is another condition necessary, and that is, that the plates be not too far apart; for it is evident, that if liquids generally are not good conductors, there will be much greater resistance, when the plates are far apart, than when close together.

The heating power of a battery may be made very great by increasing the surface, and by having a rapid chemical action. Mr. Children's battery, constructed on this principle,



melted platinum, the most infusible of all metallic bodies, as rapidly as if it were so much lead. Two pieces of boxwood charcoal brought together at each pole, become heated to intense whiteness; and this result takes place as well in vacuo or in water as in air. The galvanic light consists only of two charcoal points in vacuo, heated to intense whiteness, by having each connected with the electrode of a galvanic battery; and the fact that this takes place as well in vacuo as in air, leads to the belief that it is not combustion, but that the intense heat is due entirely to a molecular change, irrespective of combustion with oxygen.

*Electrolyzation.*—Decomposition, or chemical analysis by means of the battery, is a very important process. Two conditions are necessary, viz., 1. *That the substance to be decomposed must be a conductor*; and, 2. *It must be in a liquid form.* The process is called electrolyzation, and the thing decomposed is called an electrolyte.

The parts at which the evolution of each constituent takes place, are called electrodes, and sometimes poles, the latter being, however, a bad name, because there is a continuous circle; but both names are intended as mere expressions of a fact, without regard to any theory.

By Faraday they were called as follows: The plate from which the current sets out in the liquid, he named the *anode* (corresponding to the positive pole), and the other (corresponding to the negative pole), the *cathode*, that is, literally, the rising and setting way or door.

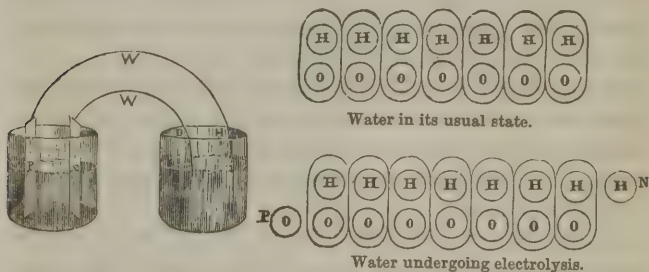
Below is a list of some of the best electrolytes:

1. A solution of iodide of potassium.
2. Fused chloride of silver.
3. Fused protochloride of tin.
4. Fused chloride of lead.
5. Solution of chlorohydric acid.
6. Water acidulated with sulphuric acid, &c.

Water itself, if pure, is a very bad conductor of electricity. It has, indeed, been denied by some, that it is a conductor at all.

When water is decomposed, however, the oxygen is disengaged at the positive pole, and is, therefore, said to be *electro-negative*, on the principle that opposite states attract each other, while the hydrogen is evolved at the cathode, and is, therefore, called *electro-positive*. If two tubes containing water are inverted over the electrodes, it will be found that the hydrogen will occupy twice as much space as the oxygen; and thus the analytical proof that water is composed of two volumes of hydrogen to one volume of oxygen, is obtained.

The manner in which the decomposition takes place, is illustrated by the following diagram :



P and Z are the plates immersed; W W the wires leading into a vessel of water; and H and O are the gases given off.

The water is supposed to arrange itself in a molecular condition between the poles or electrodes, a particle of oxygen is evolved at the anode, and its particle of hydrogen, instead of being transferred at once to the opposite electrode, unites with the next particle of oxygen, and displaces the particle of hydrogen with which it was previously united, which, on being displaced, unites with the next particle of oxygen, and so on to the last, where a particle of hydrogen is thrown off.

There is, then, a propagation of a polar force throughout the molecules of the water, and all other electrolytes, and a series of consecutive decompositions and recompositions produced.

A very striking illustration of electrolysis may be exhibited by the decomposition of a solution of sulphate of soda, coloured blue by cabbage. Place the solution in a glass vessel, and dip down a partition to divide the fluid; then place the extremities of the wires of a battery in the solution, one on each side of the partition: the sulphate of soda will be decomposed; the sulphuric acid, being evolved at the positive side, will, of course, colour the solution beautifully red, while the soda will be evolved at the opposite pole, and will colour the solution green; these being the actions of an acid and an alkali on vegetable blues.

In all cases of electrolysis, the first decomposition is into the elements, no matter what the number of these elements may be. Thus we have  $A B + C D$  within the circle of action; the primary decomposition is into the elements A and B, and C and D, and then there is a recomposition.

TABLE OF SOLID CONDUCTORS OF VOLTAIC ELECTRICITY, AND THEIR  
RELATIVE CONDUCTING POWERS.

Copper, . . . .	100	Platinum, . . . .	16
Gold, . . . .	93	Iron, . . . .	15·8
Silver, . . . .	73	Tin, . . . .	15·5
Zinc, . . . .	28	Lead, . . . .	8·8

TABLE OF LIQUID CONDUCTORS AND THEIR RELATIVE CONDUCTIBILITIES.

Saturated solution of Sulphate of Copper, . . . .	100
Add one volume of water to the above, . . . .	64
Add two volumes, . . . .	44
Add four volumes, . . . .	31
Solution of Sulphate of Soda, . . . .	41
Distilled Water, . . . .	00·25

## MAGNETISM.

Before treating of electro-magnetism, it is better to understand a few facts in relation to magnetism.

Magnetism is a property belonging to some iron ores, and a few other bodies, by means of which they attract iron and steel, and excite the same property in the bodies attracted. Again, when one of these exciting bodies, which we call a magnet, is elongated and allowed to move freely in all directions, by being suspended, it will take a position north and south, one extremity always pointing to the north pole, while the other extremity always points to the south pole; these ends being called respectively the north and south poles of the magnet.

If a steel needle be touched with this magnet in a particular way, that is, by drawing the magnet from the centre to the extremities, the needle will become a permanent magnet. If two such needles be suspended near each other, and the north pole of the one presented to the same pole of the other, they will be mutually repelled; and the same is true of their south poles.

But if the north pole of the one be presented to the south pole of the other, they will mutually attract each other; hence the law: *two similar magnetic poles repel each other, and dissimilar magnetic poles attract each other.*

Magnetism can be induced by placing a large magnet in the vicinity of steel or iron, but these will possess no polarity, either end being attracted by any extremity of the magnet; but by rubbing the iron or steel in the manner described for the needle, they will assume a polar condition.

If a magnetic needle be freely suspended by its centre of gravity, it will not remain in the horizontal condition, but it will dip, that is, its north pole will point downwards towards

the earth, making an angle of  $70^{\circ}$  with the horizon; hence it is that the mariner's compass needle must be loaded, to prevent this dip.

It has been said, in reference to the extremities of the magnet, that they point north and south. This is not, however, the case; the magnet only points north and south at the equator, while in our latitude the north pole points  $24^{\circ}$  west of the meridian. This is called its horizontal declination.

*Magnetic Induction.*—When a piece of soft iron is placed at the pole of a magnet it will be attracted, and this piece of iron will attract another piece, and so on; showing that magnetism is induced by the contact of the first magnet; for if the first piece is removed, all the rest will drop off. If a magnet bent in the shape of a horseshoe is used, and pieces attached to each pole, a cross-piece can be placed over the extremities of the two last, and a continuous circle thus formed; this experiment also shows that polarity is induced, because similar extremities would repel each other. All magnets should have pieces of iron attached to their extremities, to prevent the loss of magnetism; such pieces are called *armatures* or *keepers*.

The earth is supposed to be a great magnet, having a north and south pole corresponding to its respective geographical poles; hence the north pole of a magnet must really be the south pole, because opposite poles attract, and vice versa; therefore it is better, as is now generally done, to call the extremities the *marked* and *unmarked* poles, the marked one being north.

There are in reality two magnetic poles, one in Siberia and the other in North America.

#### ELECTRO-MAGNETISM.

It has been already shown that a magnetic needle is de-

flected by a galvanic current. If the current passes over the needle, its marked pole will be deflected to the east, and its unmarked pole to the west; but if the current passes under the needle the opposite holds good.

To know the direction of a current or the deflection of a needle, the following formula is given: Suppose yourself to be the conducting wire, and to be placed in its position; then while you are looking at the marked pole, and the current is passing from your head to your heels, it will be deflected to the right hand; if from your heels to your head, to the left hand.

A coil of copper wire connecting the poles or electrodes of a battery will be found to attract iron or steel filings precisely as a magnet does, when the battery is in action, and to cease attracting them when the circle is broken; that is, the connecting wires of a galvanic battery are magnets as long as the circle is closed.

A conducting wire placed at right angles to a steel needle will render it permanently magnetic. If the conducting wire be twisted like a corkscrew, and the needle placed inside of the cylinder thus formed, we still have a magnet, because there is a current conveyed by the wire around the needle at right angles to its direction.

Such an arrangement is called a helix, and when the wire is twisted around with the right hand, it is called a right-handed helix; with the left hand, a left-handed helix.

Now, if a steel needle be placed within such a coil, and the extremities of the coil be connected with the electrodes of a galvanic battery in action, it will become permanently magnetic, and its marked or north pole will correspond with the cathode or negative electrode of the battery, while its unmarked or south pole will correspond with the anode or positive electrode of the battery. The current commences traversing around the south pole and ends at the north. In

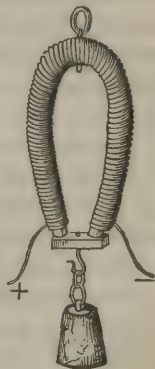


such an arrangement the current is at right angles in nearly every part of its course; and as each coil adds its effect to the others, the united action of a helix must therefore be very powerful.

Soft iron does not retain magnetism, yet while under the action of the helix, it exhibits very powerful magnetic properties. Thus, take a piece of soft iron like a horseshoe, and wrap it with copper wire at right angles to its axis, and have the extremities of this wire connected with a battery; now place an armature of soft iron on the extremities of the horseshoe bar, and it will be found to adhere with a force of many hundred pounds. The iron is, during the time the current is closed, a most powerful magnet, and such an apparatus is an electro-magnetic machine.

The magnetism thus conferred by electric currents will comport itself precisely like that of a common magnet, viz., attracting and repelling, &c.

The attracting and repelling powers of electro-magnets can be applied to rotary motion, and it has been attempted to apply this as a motor force. All that is necessary is to have the two extremities of a magnet, contiguous to a bar of soft iron, wrapped with a helix, having this latter piece so fixed that it can rotate on a pivot. Now, by conveying a current of electricity through the helix around the little bar, we confer on it polarity, and its south pole will be attracted by the north pole of the magnet, which should be a horseshoe one. But if we now interrupt the current, by means of pieces of ivory or wood fixed on the opposite sides of the rotating bar, so that the current will be reversed at each semi-rotation, we will get a continued and very rapid motion; because the



marked pole will first be attracted by the unmarked pole of the magnet, the current is then reversed by the ivory, and the marked or north pole becomes the south, which is then repelled by the south pole of the magnet, which attracted it before, while it is also attracted by the other pole of the magnet, to be again reversed and repelled.

Many varieties of these machines have been devised, but they are all constructed on the same principle ; it may be remembered, however, that instead of having ivory or any non-conductor to reverse the current, we may have right and left-handed helices on the same bar, or whatever may be used to rotate.

Rotation can be obtained without a magnet, by merely having reversed coils, one suspended so as to move freely within the other ; the inner one will rotate by the mutual attraction and repulsion of the currents.

The last experiment may be made without helices or coils, by having two fine wires, connected each with the electrode of a battery, and each wire suspended near to the other, and free to move ; now by passing currents of electricity through the wires in the same direction, there will be a mutual attraction between the wires, but in opposite directions a repulsion. This is the principle of the two coils ; the outside one is fixed, and by having a pole-changer attached, the currents are reversed ;—there is attraction and repulsion.

*Induction of Electro-magnetism.*—When a body, no matter what, conveying a current of electricity in any direction, is brought into proximity to another conducting body, not conveying electricity, the first current will induce another current through space in the second body. This can be illustrated by taking a coil of long heavy wire, and connecting it with a cell in action ; then suspend over it a coil of very fine but long wire, wrapped with cotton ; a current will now be induced in the second wire, of very great intensity,

because it, being very fine, presents great resistance, on account of the smallness of its surface; if its extremities are seized, a very severe electric shock is produced. Such a current is called a secondary one, and it may itself induce another tertiary one, and this again a fourth current, and so on.

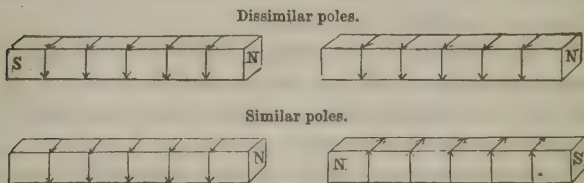
The principle above illustrated is that of the common galvanic battery, as it is called. This has a coil or helix of very coarse wire conveying a current; without this, and not in any way communicating with it, is a second coil or helix, of very fine wire, having its extremities fastened into metallic handles, to be grasped when the shock is wished. A current is induced in the last helix when the first or inner one is conveying a current. Connected with this is a horseshoe bar of soft iron, which is converted into a temporary magnet, while its helix is conducting, and attached to the extremities of the bar is an armature, capable of being attracted and repelled; this makes and breaks contact by a pole-changer, and a series of successive shocks is experienced.

The apparatus above described is called the electro-magnetic machine; but it will be obvious that, from the principle involved in its construction, a more proper name would be the *inducto-galvanic machine*.

*Magnetic Electricity.*—By magnetic electricity is meant, that of a pure magnet, unconnected with galvanism; that is, an electrical current may be had without a battery. This can be shown by the following apparatus: Take a compound horseshoe magnet, and have a large bar of soft iron, wrapped with a helix, placed within its poles; when this latter is made to revolve very rapidly, a current of pure magnetic electricity will be induced, which will not only give a spark and a shock, but will also decompose chemical compounds. A simple horseshoe magnet has a current traversing it, when the armature is attached, and this current is sufficient to de-

flex a needle. These, and many other facts, lead to the unavoidable inference, that magnetism is only a modification of galvanism or electricity.

*Earth's Influence.*—The earth is supposed to be a great magnet, having voltaic circles passing around it at right angles to its axis, from east to west; and we already know that any body, having a current of electricity traversing it at right angles to its axis, is for the time being a magnet. We now arrive at the explanation of another fact, namely, the repulsion between similar poles and the attraction between dissimilar poles of a magnet. This is because, when two similar extremities or poles of a magnet are presented to each other, we have the currents at these poles moving in opposite directions, and we already know that two currents moving in opposite directions repel each other, while those moving in similar directions attract; under which latter condition the magnets are when dissimilar poles are presented to each other.



When a bar of soft iron is held north and south, and in the line of dip forming an angle of  $70^\circ$ , it becomes a magnet for the time being. If steel is held so for two or three days it becomes a permanent magnet. This result is supposed to take place by the earth inducing a current in such a bar at right angles to its axis, it being in a proper position to receive it in such a manner, viz., in the line of dip, and pointing towards the north. Hence it is that nearly all kitchen pokers and such articles, iron tools, &c., that have been leaning in such a position possess magnetic properties.

*Thermo-Electricity.*—Electricity may be developed by heat. The conditions are that we have two conductors, one better than the other, and heat applied at the points of union. This also deflects the needle. The sun's rays may develop this, and as the heat of the sun on different parts of the earth varies at different seasons, it may be the cause of the magnetic poles of the earth varying at different seasons of the year.

*Magnetic Telegraph.*—One of the most useful of the practical applications of electro-magnetism is the magnetic telegraph. It is nothing more than the conversion of a horseshoe bar of iron into a temporary magnet, by means of a helix connected with a cell or battery. A lever is arranged in such a way that its short arm, to which an armature is attached, will be attracted by the poles of a magnet, or rather bar, while it is temporarily converted into one, while to the long arm of the lever a style is attached, the point of which is brought up to a slip of paper (revolving over a cylinder by clockwork), at the same time that the armature is attracted.

The wires of the battery may now run between any two points, and when the circle is closed at either extremity, the battery is in action; the horseshoe bar is converted into a magnet, the armature is brought down, and the style brought up to the paper. If the circle is only closed for an instant, the style is brought up for a moment and then drops, making only a point; but if the circle is closed for a longer time, a scratch is made by the paper being drawn along the point of the style. In this way, by having certain scratches and dots for signs, ideas may be communicated. The above is the principle of Morse's telegraph.

There is another telegraph of still simpler form than Morse's, called Bain's. This is only a voltaic telegraph, without a magnet at all. The paper used is prepared with a chemical preparation, in such a way that whenever the poles of the battery



are brought together in contact with it, a blue mark is made by the decomposition of certain salts in the paper; and in this way, by merely making blue marks on paper, we have a telegraph of much simpler form than the other.

The subject of electricity has only been touched on as manifested in inorganic bodies; but on examination, a very interesting field is opened up in relation to that of organic bodies. Thus we find some animals, as the gymnotus, torpedo, &c., capable of giving most powerful shocks, and it appears that the apparatus by means of which this is effected, is closely connected with their nervous systems.

A question has also arisen lately, whether electricity and nerve-force are not identical. In support of this many arguments are advanced; as that it exists, as has been stated, constantly in a state of tension in some animals, as the torpedo, &c., and in these it is connected with a series of cells forming a part of their nervous arrangement; that free electricity will excite muscular contractions in a frog's leg, &c.; that there are constant currents in animal bodies, as from alkaline mucous surfaces to acid ones; from the interior to the exterior of muscles; from their tendinous extremities to their heads; and still further, that there is an electrical discharge during every muscular contraction. This last is proved experimentally by placing a finger of each hand in a cup containing a solution of common salt; place also in the same cup the extremities of the wires of a galvanometer; and then, by suddenly and powerfully contracting all the muscles of one arm, both flexors and extensors, a deflection of the needle will take place

The present article finishes the subject of the imponderables. Concerning the nature of the forces, light, heat, and electricity, we know nothing. The phenomena manifested by them are all that we know now or probably ever will; they are to



us the ultimate facts. The idea, however, has been advanced that light, heat, electricity, and nerve-force, are modifications of one and the same great force, residing in an ethereal medium, which is, compared to our atmosphere, what the latter is to granite.

## PART II.

# INORGANIC CHEMISTRY.

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ALL bodies in nature, as a general rule, are complex, and are composed of two or more simple bodies or elements.

An element is a body that has not as yet been resolved into a simpler form; it is to us indestructible, as such; and yet it is probable that many of our elements may hereafter be discovered to be compound bodies, as the alkalies were by Davy.

The whole world embraces about 58 of these elements. Their names have been for the most part accidental, yet laying the foundation of our present system of nomenclature.

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## SECTION I.

### AFFINITY.

THE elements of which compound bodies are composed are associated together by a force called chemical attraction or affinity.

This force acts only at insensible distances and between the minutest particles; it also acts with dissimilar powers with different substances. Add salt to water, water to alcohol or sulphuric acid, and we have cases of chemical affinity; they unite, but no union would take place if oil were added to water, because they possess no affinity for each other.

*Single Elective Affinity.*—Present the body C to A B, and it separates, A B appropriating one of the constituents to itself. We have here a choice or election in the body C, which we call single elective affinity. For example, take an alcoholic solution of camphor and add water to it, a white powder is immediately thrown down, and a union has taken place between the alcohol and the water; that is, the alcohol has an affinity for both camphor and water, but that for the water is the stronger one and the camphor is displaced. A very common illustration is the decomposition of soap by the addition of an acid. Soap is a compound of an oil and an alkali; the acid has a stronger affinity for the alkali than the alkali has for the oil, and the oil is separated.

*Double Elective Affinity.*—Present A B to C D, and we get A C and B D. Thus, nitrate of lime is A B, and carbonate of ammonia is D C. Mix a solution of each and we will get nitrate of ammonia, A C, and carbonate of lime, B D; that is, the affinities tending to separate these are stronger than those tending to keep them in combination; or in other words, the sum of the affinities of nitric acid for ammonia, plus carbonic acid for lime, is greater than that of nitric acid for lime, plus carbonic acid for ammonia.

The terms *quiescent* and *divellent* have been given to these opposing affinities, the action of the former being to prevent change, the latter to produce it.

Here a general law, applicable to all cases of double elective affinity or double decomposition, may be stated, as follows :  
*Whenever any two soluble compounds in solution are presented*

*together, of such a character that the result of a union between any of the constituents of those compounds will be an insoluble body, then a decomposition will take place, and that insoluble compound will be formed.*

#### CHANGES ACCOMPANYING CHEMICAL ACTION.

1. Compounds lose their old properties and acquire new ones, as by adding an acid to an alkali, the properties of each are neutralized, and a salt is got, a body differing entirely from both.

2. Two bodies after combination never occupy the same space which each did separately; it is either less, and consequently has a greater specific gravity than the mean of the constituents, as alcohol and water, or greater, as by firing gunpowder, which is only a union of its constituents with oxygen.

3. Changes of temperature always accompany chemical action. Heat is evolved, as by adding sulphuric acid to water; or cold is produced, as with frigorific mixtures, &c.

4. Change of form. The two gases, chlorohydric acid and ammonia, when mixed, will give rise to the solid chloride of ammonium.

5. Changes of colour. This comes under the head of precipitates, and these changes are very important as tests. There are no uniform relations observed, and each change in colour has to be studied as an isolated fact.

#### CIRCUMSTANCES MODIFYING AFFINITY.

1. Cohesion opposes affinity for a very obvious reason, which is, that very few of the molecules can come within the sphere of the affinities. An illustration, familiar to all, is the common effervescing powder; mix them while in a solid state, and no effect will take place, but destroy the cohesion, by

bringing the constituents into a state of solution with water, and a very strong chemical union takes place. Again, pour nitric acid on a bit of solid copper, and there will be little effect produced, but pour the acid on fine copper filings, and a violent action takes place, producing a dense cloud of orange-coloured fumes.

Cohesion is overcome by mechanical division, and by liquefying, either by a soluble vehicle or by heat.

2. Insolubility. (See General Law, page 79.)

3. Elasticity opposes affinity. This would not be expected, when it is remembered that cohesion opposes affinity also. But oxygen and hydrogen mixed, may be preserved for any length of time, without any chemical union whatever, although their affinities for each other are very great. An apt illustration also is the atmosphere, consisting of nitrogen and oxygen, which form five distinct compounds when united chemically, yet in the air we have only a mechanical mixture.

4. Quantity of matter is a modifying cause. This is apparent at once, for water will dissolve a small quantity of salt more rapidly than a large one.

5. Gravity exerts the same effect; but this is very trifling, unless the difference in densities be very great.

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## SECTION II.

### LAWS OF CHEMICAL COMBINATION.

SOME bodies combine in all proportions, while others unite in very few. Concerning the first, no laws are necessary, nor, indeed, can be made, for a drop of alcohol may be diffused through a gallon of water, &c.

But the last, namely, those combining in few proportions,

form very interesting groups of compounds, their laws being as follows :—

1. *Law of Definite Proportions.*—The proportions in which two or more bodies combine to form a compound, are definite and invariable. No circumstances can modify this law, as temperature, climate, &c., and whether found in nature, or the product of art, the elements entering into the same compound, will be found by weight to be the same. Thus, when sulphuric acid is presented to baryta, the same definite compound, sulphate of baryta, will always be obtained, and its constituents will always hold the same proportion to each other. So when hydrogen is burned in oxygen, water is invariably the product.

2. *The Law of Equivalents.*—The proportions expressed in numbers, in which several bodies combine with any given body, represent the proportion in which such bodies combine with each other.

Thus, take the body oxygen: it is found that 8 parts of it, say 8 grains, will combine with 16 grains of sulphur, 36 grains of chlorine, and 6 grains of carbon; then these bodies will combine with each other in the same proportion; that is, sulphur with carbon in the proportion of 16 to 6. These proportions are called *equivalents*, because 36 grains of chlorine are equivalent to 16 grains of sulphur in combining with hydrogen or any other body.

This law is true, not only of simple bodies, but of all compound bodies, their combining numbers or equivalents being equal to the sum of the combining numbers or equivalents of the elements entering into their constitution. Thus, sulphuric acid is composed of sulphur, 16 and 3 parts by weight of oxygen, that is 3 times 8, which is 24; therefore the equivalent number for sulphuric acid is  $16 + 24 = 40$ . Again, nitric acid is composed of nitrogen 14, and 5



equivalents of oxygen, 40; hence its equivalent number is  $14 + 40 = 54$ .

The numbers above noticed, represent the equivalents of the bodies mentioned, that is, the proportions in which these bodies will unite with other bodies, simple or compound.

When weight is said, the absolute weight is not meant in all cases; but it is meant that combinations always take place in proportion to such weights. Thus, oxygen may combine in the proportion of  $\frac{8}{16}$  of a grain, or 8 grains, or 80 grains, &c., with  $\frac{6}{12}$  of a grain of carbon, or 6 grains, or 60 grains, &c. Still further, the weights may be anything; that is, 4 grains of oxygen may combine with some other body; yet it will be found uniting in the proper proportion, as, for instance, with 8 of sulphur, that is, in the proportion of 8 to 16; or 3 of carbon, that is, 8 to 6; or 18 of chlorine, that is, 8 to 36, &c., &c.

3. *The Law of Multiple Proportions.*—When bodies combine in more proportions than one, the corresponding numbers are in some series of simple multiples. These multiple bodies seldom unite in more than seven proportions.

The following illustration will explain the law at once. The body A will unite with B in the proportion of

A+B

A+BB or 2B.

A+BBB or 3B.

A+BBBB or 4B.

A+BBBBB or 5B.

The above is the simplest form of a multiple, viz., 1 to 1, 1 to 2, &c., and the combinations of nitrogen with oxygen are a good example of it.

	Nitrogen 14.	Oxygen 8.
Nitrous Oxide, . . . . .	.	N+O
Nitric Oxide, . . . . .	.	N+2O

Hyponitrous Acid, . . . . .	N+30
Nitrous Acid, . . . . .	N+40
Nitric Acid, . . . . .	N+50

Sometimes the body A unites in the following proportions with B, viz. :—

$$2A+3B.$$

$$2A+5B.$$

$$2A+7B.$$

Some of the combinations of phosphorus, iron, &c., follow the last form.

The above laws of combination form the foundation of the science of chemistry.

*Method of obtaining Equivalent Numbers.*—In order to ascertain the equivalent proportions in which bodies combine, a definite compound of two simple substances can be taken, as water, which is composed of oxygen and hydrogen, each of which has an extensive range of affinity. On analyzing water, it is found to contain 8 parts by weight of oxygen, and 1 part by weight of hydrogen; then if it be assumed that water is composed of one equivalent of each, their relative weights, that is, their equivalents, will be 8 and 1. The relative weights of other bodies may now be obtained by combining them with 1 grain of hydrogen or 8 grains of oxygen, being always careful to ascertain that not more than one equivalent of the body to be determined combines with the body whose equivalent is known. It will be obvious now, that hydrogen, which is assumed as 1, may be any number, and the proportions will still be the same for all the rest, provided they be multiplied by the same number. Or oxygen may be assumed as the unit; if it is called 100, then hydrogen will be 12.5, &c. This last plan is very frequently used in France and Germany; to bring it to our standard, viz., hydrogen as unity, all that is necessary to do is to

divide the numbers by 12.5; thus, oxygen  $100 \div 12.5 = 8$ , which is its equivalent with us.

By knowing the above laws, and the combining numbers, analyses of chemical compounds are made.

*Atomic Theory.*—It was supposed at one time that all bodies must combine by atoms, and that the combining numbers expressed the weights of these ultimate indivisible atoms; thus, an atom of oxygen would weigh 8, of carbon 6, &c. This, however, is, and must always be, only an hypothesis, for it is utterly impossible to conceive an idea of an atom, without that idea gives it space, and if it have space it can be divided.

*Law of Volumes.*—When gases combine, they effect their combinations in simple proportions or ratios of volume; that is, one cubic foot with one cubic foot, or one cubic inch with one cubic inch, or one cubic foot with two cubic feet, &c.; thus, a gallon of hydrogen will unite with a gallon of chlorine, and form chlorohydric acid gas, occupying two gallons. This law is as fixed as that of combinations by weights. It is stated as follows:—*The combining volumes of both elementary and compound gases are either equal, or have the simple ratio of 1 to 1, or 1 to 2, 1 to 3, &c.*

The volume of hydrogen is assumed as the unit.

#### NOMENCLATURE.

The names applied long ago to chemical elements, are still retained; while newly discovered elements are named for some striking property: thus oxygen was supposed to be the universal acidifying principle, hence its name, from *οξύς*, *acid*, *γεννέιν*, to generate. The language adopted for compounds was intended to be such that the mere name would express their composition. Thus it was found that oxygen united in more proportions than one, therefore the termination *ic* was given to the higher degree of oxidation, and *ous* to the

lower. Again, these oxides united with bases and formed salts, and the same principle was pursued; thus an acid in *ic* became *ate* in the salt, and an acid in *ous* became *ite* in the salt; as sulphuric acid gives a *sulphate*, and sulphurous acid a *sulphite*.

The termination *uret* denotes simple combinations of non-metallic bodies with each other, or with metals and their oxides.

Different degrees of oxidation are distinguished by prefixes from the Greek or Latin. *Protoxide* signifies the first degree of oxidation, *binoxide* the second, *teroxide* the third, and so on, while *peroxide* signifies the highest degree. The same prefixes are used for the sulphurets, carburets, &c.

The idea of giving a name which will be expressive of all constituents of the compound, has been found to be impossible for a vast number of bodies. Take the salt, called yellow prussiate of potash, called also the ferro-cyanide of potassium, and neither name will tell the constituents, much less the proportions of them, entering into that body.

*Chemical Symbols.*—The impossibility of contriving names expressive of the constituents of compounds, led to a new system of nomenclature, called symbols. The initials of the Latin or scientific names are chosen, and by arranging these in various ways, we have absolute expressions of any compounds, telling at once the constituents, the proportions, and the number of those proportions.

Instead of designating the body water by that name, it is called by symbols  $\text{HO}$ , which indicates at once its constitution, H being the initial for hydrogen, and O for oxygen. Sulphuric acid is  $\text{SO}_3$ , sulphurous acid  $\text{SO}_2$ , nitric acid  $\text{NO}_5$ , &c. These tell to the eyes the constituents, &c., and are called *chemical formulæ*.

The numbers placed beside symbols multiply those symbols, and when no number is placed, 1 is understood;  $\text{O}_3$ ,

means three equivalents of oxygen, and  $\text{SO}_3$ , means one equivalent of sulphur, united to three equivalents of oxygen.

A number placed before a compound, multiplies all that follows in that compound.

The above rules can all be illustrated by the body called alum, which is chemically a sulphate of alumina and potassa; its formula is  $\text{SO}_3, \text{KO} + 3\text{SO}_3, \text{Al}_2, \text{O}_3 + 24\text{HO}$ . The first,  $\text{SO}_3, \text{KO}$ , indicates sulphate of potassa; it is 1 of sulphur and 3 of oxygen, forming sulphuric acid, united to one of potassium and one of oxygen, forming potassa; the next,  $3\text{SO}_3$ , indicates 3 equivalents of sulphuric acid, that is, 3 of sulphur, and 9 of oxygen, united to the sesquioxide of aluminum, represented by  $\text{Al}_2, \text{O}_3$ , forming sulphate of the sesquioxide of aluminum, or sulphate of alumina; and to the whole is added 24 of oxygen and 24 of hydrogen, forming 24 equivalents of water. It is thus a sulphate of potassa, plus a sulphate of alumina, plus 24 equivalents of water.

There are other laws connected with this subject, which will be explained when we arrive at the cases themselves.

### SECTION III.

#### SIMPLE BODIES.

Bodies.			Symbols.			Equivalents.
Oxygen,	.	.	O	.	.	8.
Chlorine,	.	.	Cl	.	.	35.41
Bromine,	.	.	Br	.	.	78.26
Iodine,	.	.	I	.	.	126.36
Fluorine,	.	.	Fl	.	.	18.26
Hydrogen,	.	.	H	.	.	1.
Nitrogen,	.	.	N	.	.	14.06
Carbon,	.	.	C	.	.	6.

Bodies.	Symbols.	Equivalents.
Sulphur, . . .	S . . .	16·
Selenium, . . .	Se . . .	39·57
Phosphorus, . . .	P . . .	31·38
Boron, . . .	B . . .	10·90
Silicon, . . .	Si . . .	28·18
Potassium, . . .	K . . .	39·19
Sodium, . . .	Na . . .	23·27
Lithium, . . .	L . . .	6·43
Barium, . . .	Ba . . .	68·55
Strontium, . . .	Sr . . .	43·78
Calcium, . . .	Ca . . .	20·
Magnesium, . . .	Mg . . .	12·67
Aluminum, . . .	Al . . .	13·69
Glucinium, . . .	G . . .	26·50
Zirconium, . . .	Zr . . .	33·62
Yttrium, . . .	Y . . .	32·20
Thorium, . . .	Th . . .	59·89
Manganese, . . .	Mn . . .	27·67
Iron, . . .	Fe . . .	27·14
Zinc, . . .	Zn . . .	33·
Cadmium, . . .	Cd . . .	55·74
Cobalt, . . .	Co . . .	29·52
Nickel, . . .	Ni . . .	29·57
Copper, . . .	Cu . . .	31·65
Bismuth, . . .	Bi . . .	70·95
Lead, . . .	Pb . . .	103·56
Tin, . . .	St . . .	58·82
Cerium, . . .	Ce . . .	45·98
Lanthanum, . . .	Ln . . .	
Uranium, . . .	U . . .	60·
Antimony, . . .	Sb . . .	129·04
Arsenic, . . .	As . . .	75·21
Chromium, . . .	Cr . . .	28·14
Vanadium, . . .	V . . .	68·55
Molybdenum, . . .	Mo . . .	47·88
Tungsten, . . .	W . . .	94·64
Columbium, . . .	Ta . . .	184·59
Tellurium, . . .	Te . . .	64·14



Bodies.	Symbols.	Equivalents.
Titanium, . . .	Ti . .	24.29
Mercury, . . .	Hg . .	202.59
Silver, . . .	Ag . .	108.12
Gold, . . .	Au . .	99.44
Platinum, . . .	Pt . .	98.68
Palladium, . . .	Pd . .	33.77
Rhodium, . . .	R . .	52.11
Iridium, . . .	Ir . .	98.68
Osmium, . . .	Os . .	99.56

The simple or elementary bodies enumerated in the above table, are divided into metallic and non-metallic bodies; the first thirteen are non-metallic, viz., oxygen, chlorine, bromine, iodine, fluorine, hydrogen, nitrogen, carbon, sulphur, selenium, phosphorus, boron, and silicon; all the rest are metallic.

Some of the simple non-metallic bodies are divided into two great classes, called *amphigen* and *halogen* bodies.

1. *Amphigen Bodies*.—These are those bodies which form both acids and bases; the term is derived from two Greek words, meaning *generator of both*. Oxygen, which is the type of all simple bodies, is the especial type of the amphigen class.

They are—

Oxygen,  
Sulphur,  
Selenium,  
Tellurium.

2. *Halogen Bodies*.—These are termed so, because they form salts resembling sea salt (chloride of sodium).

They are—

Chlorine,  
Bromine,  
Iodine,  
Fluorine,

to which is added a compound body—

### Cyanogen.

Four of the above elements, viz., oxygen, chlorine, hydrogen, and nitrogen, when uncombined, always exist in the form of a gas; the rest are solid or liquid.

Gases must be collected over water, brine, or mercury, as the case may be. They are collected by means of a pneumatic cistern, which is nothing more than a vessel capable of holding water, or mercury, or brine, having a shelf pierced with holes, so as to permit a pipe conveying gas to pass through from below. The shelf is under the level of the fluid used, and the gas is got in receivers, generally glass; these latter are filled with the liquid contained in the cistern, and inverted over the pipe; they remain full by atmospheric pressure; but when the gas is passed through, it ascends and displaces the liquid in the receiver until sufficient gas is collected in it. The receivers may now be transferred to any place, by placing them mouth downwards in dishes of water, or brine, or whatever is used.

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## SECTION IV.

### CHEMISTRY OF SIMPLE NON-METALLIC BODIES.

#### I. OXYGEN.

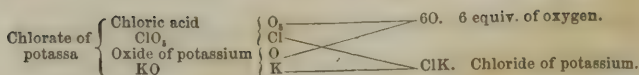
Symbol,	.	.	.	.	.	.	O
Equivalent number,	.	.	.	.	.	.	8
Specific gravity,	.	.	.	.	.	.	1.102
100 cubic inches, weigh	.	.	.	.	.	.	34.19 grains.
Volume,	.	.	.	.	.	.	$\frac{1}{2}$ or 50.

Oxygen is found in all organic and inorganic nature; it combines with all the simple bodies, and many of the compound ones; it forms 40 per cent. of the entire weight of the globe, and it is one of the great constituents of our atmosphere.

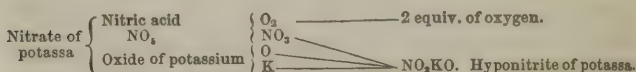
It was discovered in the year 1774, by Scheele and Dr. Priestley, independently of each other; the latter called it dephlogisticated air, on the principle that heat was due to the escape of a body called phlogiston, and oxygen being obtained by heating a body, was called dephlogisticated air. Lavoisier called it oxygen.

Oxygen is not found free in nature, hence some one of its many compounds must be used to obtain it; when got, it is always in the form of a gas. It is obtained very readily by heat, from the bioxide of manganese, nitrate of potassa, chlorate of potassa, &c.; that obtained from manganese is impure. The purest is got from the chlorate of potassa, by heating it with  $\frac{1}{10}$  of its weight of the bioxide of manganese; the gas is given off at a low red heat, and should be collected over water. The rationale is as follows: the oxide of manganese merely acts as a katalytic\* body, while the chlorate of potassa is decomposed, the chloric acid, which contains 5 equivalents of oxygen, yields them up, and the potassa yields up its single equivalent of oxygen, making 6 equivalents of oxygen given off, while chlorine and potassium alone remain in the retort, forming chloride of potassium.

\* By *katalysis*, is meant the doctrine of presence; or, in other words, when a body is present, and disposes some compound body to be decomposed, without at the same time itself entering into the round of affinity, it is called a *katalytic body*. It still remains a doubtful question in chemistry, or it is a mere question of words, whether any body can exert such an agency merely by its presence.



Oxygen gas is also readily obtained by heating nitre (nitrate of potassa) in an iron retort to redness.



The latter process yields two equivalents of oxygen, and the nitric acid is converted into hyponitrous acid, which, uniting with the potassa, forms hyponitrite of potassa.

Oxygen gas when pure is colourless, has neither taste nor smell, is a non-conductor of electricity, and therefore electro-negative, and is the sustaining principle of animal life and all ordinary combustion. It is heavier than atmospheric air, 100 cubic inches weighing 34.19 grains; its specific gravity is therefore 1.102.

Oxygen is neither acid nor alkaline; it combines with all simple bodies, which are then said to be oxidized; the process is combustion, whether it take place slowly, without light or heat, or rapidly, with the evolution of both.

Bodies burn more rapidly in oxygen than in the open air; steel is entirely consumed, and the products of its combustion are various oxides of iron; when carbon burns in it, carbonic acid is the result; sulphur, sulphurous acid; phosphorus, phosphoric acid (while the latter is burning it gives out a most intense white light); but when sodium or potassium are burned in oxygen, we get the alkalies soda and potassa. Oxygen then forms acid, alkaline, neutral, and complex bodies.

The lowest compound that oxygen forms, is called the protoxide; the second, bi or deutoxide; the third, ter or tri-

toxide, &c. ; but when we have the ratio of 1 to  $1\frac{1}{2}$  or 2 to 3, the term sesqui is employed. Thus

FeO	.	.	.	.	.	Protoxide of iron.
FeO <sub>2</sub>	.	.	.	.	.	Bioxide “
FeO <sub>3</sub>	.	.	.	.	.	Tritoxide “
Fe <sub>2</sub> O <sub>3</sub>	.	.	.	.	.	Sesquioxide “

There are compounds of oxygen, as some of those with manganese, that can have no terminology expressive of their constitution.

Bodies that have been burned lay aside their combustibility ; they are increased in weight also by as much as the amount of oxygen consumed.

Oxygen is the supporter of combustion in our animal bodies, and we are continually taking it into the lungs for that purpose ; but pure oxygen alone cannot be breathed for any length of time, without causing death from over stimulation.

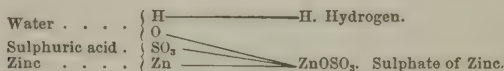
## II. HYDROGEN.

Symbol	.	.	.	.	.	H.
Equivalent number	.	.	.	.	.	1.
Specific gravity	.	.	.	.	.	0·0689.
100 cubic inches weigh	.	.	.	.	.	2·14 grains.
Volume	.	.	.	.	.	1 or 100.

This gas was formerly called inflammable air, from its combustibility, but the name hydrogen is the one by which it is now alone known. It was isolated by Cavendish, in 1776, who obtained it by decomposing steam, by passing it over red hot iron filings : the iron removes the oxygen and the hydrogen escapes ; it can then be collected over water, for which it has but a feeble affinity. Hydrogen may also be obtained by the action of a galvanic battery on water ; oxygen is evolved

at the positive pole, therefore called electro-negative, while hydrogen is evolved at the negative pole, and is therefore electro-positive.

Another method, and that which is most employed for obtaining hydrogen, is by the action of zinc on water in the presence of sulphuric acid; the latter is supposed to act as a katalytic body, but this is in reality not the case, for the acid merely dissolves off the oxide of zinc as rapidly as it is formed, and thus always presents a bright metallic surface to act on the water. The rationale is as follows: the zinc decomposes the water by uniting with its oxygen, hydrogen is set free, and the acid then unites with the oxide of zinc, forming sulphate of zinc.



Hydrogen was named from two Greek words, ὕδωρ, water, and γεννέιν, to generate. When pure it is colourless, has neither odour nor taste, and refracts light powerfully. It always retains its gaseous form, and is the lightest body in nature, being 16 times lighter than oxygen; hence 100 cubic inches weigh only 2.14 grains, and its specific gravity is 0.0689.

Hydrogen is neutral, that is, it does not change the blue colour of vegetables, is sparingly absorbed by water, cannot support respiration or combustion, but is itself eminently combustible; it is in fact the very type of inflammable bodies.

By combustion is meant the union of a body with oxygen or any other substance which gives off heat during that combination. The amount of heat given off during combustion is always in proportion to the amount of the supporter of combustion that is consumed; and this has no regard to time, for a pound of iron, while rusting or being oxidized, gives off



just as much heat as the same amount burnt up in oxygen in five minutes.

The flame of burning hydrogen gives off very little light, because all flame is gaseous, that is, it is gas heated to a white heat; and the light it gives off depends on the amount of deposition of solid matter in the flame, hence hydrogen, having none, emits no light.

Hydrogen may be set on fire when in contact with air or oxygen gas by flame, by a solid body heated to redness, and by an electric spark. For detonating purposes the best mixture with air is two measures of hydrogen and four or five of air; but the most violently explosive compound is that made with one measure of oxygen and two of hydrogen, these being just the proportions for forming water.

If a long glass tube, open at both ends, is placed over a jet of burning hydrogen, a musical note is obtained, and the whole inner surface of the tube is covered with moisture. The note is due to a series of rapid explosions, which cause a vibration of the column of air within the tube; the moisture is caused by the production of the vapour of water by the burning of hydrogen.

When a jet of hydrogen is made to play on a piece of spongy platinum, the hydrogen is fired. This result has also been ascribed to katalysis; but it is asserted that the firing takes place on account of the immense condensation of the hydrogen and oxygen gases, which takes place in the spongy body, and they are thus brought as it were, atom to atom, or within the spheres of their molecular attractions. If the platinum is diluted with clay and placed in a mixture of the two gases, they will be made to combine chemically, but no explosion is produced.

A large quantity of heat is evolved during the combustion of hydrogen; the apparatus which best illustrates this is Hare's compound blowpipe, which is merely an arrangement

connecting the pipes of two gasometers, one holding oxygen, the other hydrogen; the gases are mixed just before their escape to prevent an explosion. This apparatus is supposed to produce the most intense heat known to man; it fuses the most refractory substances. A burning jet of this thrown on lime constitutes the Drummond light, which was, however, first discovered by Professor Hare.

There are two oxides of hydrogen, viz., the protoxide (water) and the peroxide.

#### WATER.

##### PROTOXIDE OF HYDROGEN.

Formula,	. . . . .	HO
Equivalent,	. . . . .	1+8=9.
Specific gravity,	. . . . .	1.

Water is the result of the combination of hydrogen and oxygen, in the proportion of 2 volumes of the former to 1 of the latter. This is proved synthetically by firing, by an electric spark, a mixture of 2 volumes of hydrogen and 1 of oxygen; the sole result is water, the weight of which is exactly equal to the sum of the weights of the two gases.

It can now be understood why oxygen, which is bulk for bulk 16 times heavier than hydrogen, should have 8 for its equivalent number instead of 16. It is because hydrogen unites with oxygen in the proportion of 2 to 1; that is, 1 volume of hydrogen is twice as large as 1 volume of oxygen, and, therefore, 100 gallons of hydrogen will unite with 50 gallons of oxygen only.

But 100 volumes of oxygen is 16, compared to 100 volumes of hydrogen as 1, hence 50 volumes of oxygen, or one-half, is only 8 compared to 100 volumes or 1 equivalent of hydrogen. It is now generally believed that oxygen combines by half a volume with hydrogen.

The analytical proof of the constitution of water has

already been seen, in the production of hydrogen by a galvanic current.

Water is, when pure, transparent, colourless, tasteless, and inodorous; it is a powerful refractor of light, and a bad conductor of heat and electricity. Its greatest density is at  $40^{\circ}$  Fahrenheit; it freezes at  $32^{\circ}$ , and boils under the pressure of the atmosphere at  $212^{\circ}$  Fahrenheit. It evaporates at all temperatures. One cubic inch, at  $62^{\circ}$  Fahrenheit, weighs 252.46 grains; hence it is 815 times as heavy as atmospheric air.

The water of nature is always impure, owing to its extensive range of affinities. It always contains atmospheric air, which is very rich in oxygen, containing from 27 to 34 per cent., while common air has only 21 per cent. It also contains ammonia, nitric acid, chlorohydric acid, carbonic acid, salts, &c. Freshly-fallen snow, affords water tolerably pure; but to get it entirely so, it should be distilled.

#### FUNCTIONS OF WATER.

1. *A Neutral Body*.—It is remarkable for its want of activity; hence its great solvent powers, which far exceed those of any other liquid known.

2. *A Feeble Acid*.—We mean by the term acid, the property which it has of uniting with a base. Thus, potassa has almost always some water present in it, and when it is perfectly dry, its causticity is much greater than that of the hydrate, proving the neutralizing effect of water.

3. *A Feeble Base*.—Acids cannot exist as such without water. Dry sulphuric acid, as shall be seen, exerts no acid properties at all until water is present. The water acts as a base to it, which base may be substituted by a more powerful one, as the oxide of zinc, and then, instead of having a sulphate of the oxide of hydrogen, a sulphate of the oxide of zinc is obtained.

4. *Constitutional Water in certain Salts.*—Some salts, as the sulphate of magnesia (Epsom), cannot exist without water; if by heat all the water is driven off, the salt is destroyed. The formula for Epsom salts is  $\text{MgO}, \text{SO}_3 + \text{HO} + 6\text{HO}$ : the last 6 equivalents of water ( $6\text{HO}$ ) may be driven off by heat, without destroying the salt, but when the first equivalent ( $\text{HO}$ ) is expelled, the salt is destroyed; it is necessary to its constitution.

5. *Water of Crystallization.*—Take the same case above, viz., Epsom salt,  $\text{MgO}, \text{SO}_3\text{HO} + 6\text{HO}$ . The last 6 equivalents of water ( $6\text{HO}$ ), are water of crystallization, and when they are driven off, the *crystals* are destroyed.

#### BI OR PEROXIDE OF HYDROGEN.

Formula,	. . . . .	$\text{HO}_2$
Equivalent,	. . . . .	$1+16=17$
Specific gravity,	. . . . .	1.452

The peroxide of hydrogen is made by decomposing a substance containing much oxygen, as the peroxide of barium, by chlorohydric acid in the presence of water. The process requires ice, to keep the materials cool.

The oxygen is in its nascent state, and instead of escaping, unites with the water, forming oxygenated water, or bioxide of hydrogen. Chloride of barium remains. The peroxide of hydrogen is a colourless, transparent, inodorous liquid, possessing strong bleaching powers. It has a metallic taste, becomes thick by evaporation, effervesces at slight elevations of temperature, above  $55^\circ$ , owing to escape of oxygen, and explodes violently at  $212^\circ$ . It is decomposed by metals and metallic oxides.

*Ozone.*—The name ozone has been given to a hypothetical substance, supposed to be the cause of the smell perceived when electric discharges are made. The same odour is also

observed when phosphorus is brought in contact with a little water. The odour is cool and peculiar. The substance has not been isolated, although it is supposed by some to be a new form of peroxide of hydrogen. Paper moistened with a solution of iodide of potassium and starch is said to be made blue by it, owing to a precipitate of free iodine, which then colours the starch. It was absurdly believed to be a cause of epidemic cholera.

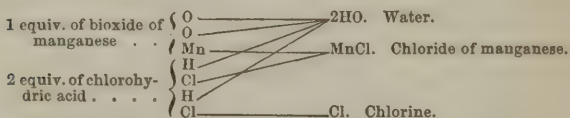
### III. CHLORINE.

Symbol,	. . . . .	Cl
Equivalent,	. . . . .	35.41
100 cubic inches weigh,	. . . . .	76.6 grains.
Specific gravity,	. . . . .	2.47
Volume,	. . . . .	1 or 100.

When common salt (chloride of sodium) is acted on by sulphuric acid, a gas, called marine or muriatic acid, is obtained. When this muriatic acid is brought in contact with the oxide of a metal, a suffocating, irrespirable gas is given off, which was at one time supposed to be *oxymuriatic* acid, and that the oxygen was obtained from the oxide of the metal employed. Sir H. Davy attempted to decompose this body, but failing in his attempt, he inferred that, instead of being a compound body, it was a new element, which he called chlorine, from a Greek word, *χλωρος*, green.

Chlorine is prepared by adding chlorohydric acid (muriatic) to the bioxide of manganese, or the bichromate of potassa, in a glass retort, and applying a gentle heat. To understand the principle of its production, it is necessary to know that chlorohydric acid is composed of one equivalent of chlorine, and one of hydrogen, its formula being  $\text{HCl}$ . Two equivalents of the acid are added to one equivalent of the bioxide of manganese, and the following reactions take place: both

bodies are decomposed into their elements; the two equivalents of oxygen in the bioxide unite with the two equivalents of hydrogen of the acid, forming two equivalents of water, then the manganese unites with one of chlorine, forming chloride of manganese, and the other equivalent of chlorine is set free. The chlorine should be collected over warm water in glass receivers.



By symbols,  $\text{MnO}_2$  and  $2\text{HCl}$  yield  $\text{MnCl}$ ,  $2\text{HO}$ , and  $\text{Cl}$ .

Chlorine is a yellowish-green gas, with an astringent taste and a disagreeable odour. It is totally irrespirable, even when much diluted, producing spasm of the glottis. It is very heavy; 100 cubic inches weigh 76·6 grains: hence its specific gravity is 2·47, air weighing 31·012 for 100 cubic inches.\*

Chlorine is somewhat soluble in cold water, hence it is collected over warm water. It has but a feeble affinity for oxygen, but a strong one for hydrogen and the metals. It will disappear when kept over water, owing to the formation of chlorohydric acid, which is very soluble in water; oxygen is at the same time liberated; hence chlorine is indirectly a good oxidizing agent. The production of chlorohydric acid only takes place in the presence of light; or if the chlorine is obtained in the dark, no such result will take place. These are termed its allotropic states.

When chlorine gas, in presence of water, is exposed to a

\* Under the pressure of 4 atmospheres, chlorine is a limpid liquid, of a bright yellow colour, which does not freeze at zero, and which becomes gaseous with ebullition, as soon as the pressure is removed.



cold of  $32^{\circ}$ , yellow crystals are formed, which are a definite compound, composed of 1 equivalent of chlorine and 10 of water.

One of the most important properties of chlorine is its bleaching power; this it may do either by removing the hydrogen of the water used in the process, and the oxygen, which is thus set free, acts on the colour; or it may destroy the colour directly by removing its hydrogen, which may be intrinsic to it, and its integrity thus be destroyed.

Chlorine is a supporter of combustion, that is, bodies unite with it chemically, with the production of light and heat. Phosphorus, finely divided, antimony, gold leaf, arsenic, and many other metals, take fire in it spontaneously, and the products of the combustion are chlorides. Its affinities are almost as universal as those of oxygen, and hence for every *oxide* there is a corresponding *chloride*.

*Tests.*—Chlorine is recognised by its colour, which is green, and its odour, which is peculiar; its bleaching powers are also sufficient in most cases to detect it. The best test is a soluble salt of silver, as the nitrate; with this a white chloride is precipitated, which becomes darker on exposure, is insoluble in acids, but soluble in pure ammonia.

Chlorine stands at the head of a family called the halogen bodies; the rest of those comprising the group are bromine, iodine, fluorine, and cyanogen. So great a resemblance exists between these bodies in most of their relations, that the history of one serves for all.

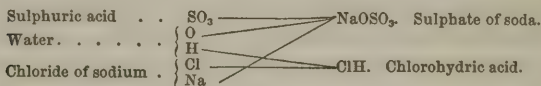
## CHLOROHYDRIC ACID.

Formula, . . . . .	HCl.
Equivalent, . . . . .	36.41
Specific gravity (gas), . . . . .	1.27
100 cubic inches weigh, . . . . .	39.36 grains.
Volume, . . . . .	200.

Chlorohydric acid has been known by the name of hydrochloric, muriatic, and marine acid. It is chemically a chloride of hydrogen.

If we mingle equal volumes of hydrogen and chlorine gases, and expose them to the sun's light, they will unite and form chlorohydric acid gas.

The common method of preparing the gas, is to act on a solution of chloride of sodium (common salt) by sulphuric acid, in a glass retort. If the gas is wanted as such, it should be collected over mercury, but if it is wanted in solution, it may be collected in water, which absorbs it as fast as it passes over.



By symbols, the reaction is thus :  $(\text{S} + 3\text{O}) + (\text{H} + \text{O})$ , and  $\text{Na} + \text{Cl}$  yield  $(\text{Na} + \text{O}) + (\text{S} + 3\text{O})$  and  $\text{H} + \text{Cl}$ .

It will be seen, by referring to the diagram, that the sulphuric acid does not unite with sodium, but with its oxide (soda), because no oxy-acid can unite with an elementary body ; it can only unite with an oxy-base.

The gas is colourless, fumes strongly in the air, from condensing moisture, and has an acid suffocating odour. It becomes liquid under a pressure of 40 atmospheres. Specific gravity, 1.27.

It is non-combustible, and a non-supporter of combustion.

One of the most obvious properties of the gas under consideration, is its great avidity for water. On exposing the gas to water, its absorption takes place so rapidly, that the water is forced up into the vessel containing it, with the same violence as into a vacuum. Water absorbs 480 times its bulk, at the temperature of  $40^\circ$ , and the solution has a specific gravity of 1.21.

This acid is most commonly used in solution; it is manufactured for commercial purposes from equal weights of sea salt, water, and sulphuric acid. The pure acid is a colourless liquid, intensely sour, reddens litmus paper, fumes on exposure, and combines with water in all proportions. It freezes at  $60^{\circ}$  F., and boils at  $110^{\circ}$ .

The acid of commerce, common muriatic acid, is not pure, and is always yellow. It contains iron, sulphurous and sulphuric acids, nitric acid, &c.

A mixture of one measure of nitric with two measures of chlorohydric acid, constitutes *aqua regia*, a solvent for gold and platinum.

Pure dry hydrochloric acid exerts no acid properties at all, until water is present; the latter alone brings out its acid properties. When it is added to a metal, the hydrogen is displaced, and a chloride of the metal is the result, instead of a chloride of hydrogen. The opinion on this ground is maintained, that it is not an acid at all, that it is a salt; or in other words, that a chloride of hydrogen is as much a salt as a chloride of zinc is; for when zinc is added to the chloride of hydrogen, the latter is eliminated, the zinc taking its place, and a haloid salt thus obtained. Hence, if the chloride of hydrogen is an acid, the chloride of zinc is also an acid. On the same ground too, the idea has been advanced that hydrogen is the vapour of some metal, inasmuch as all gases are but vapours.

*Tests.*—Chlorohydric acid is distinguished by its odour, volatility, fumes, and by its white curdy precipitate with the soluble salts of silver. It is distinguished from chlorine by its want of bleaching powers.

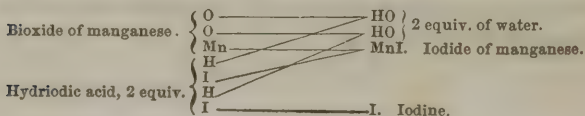
The oxy-compounds of chlorine will be treated, after iodine and bromine are disposed of.

## IV. IODINE.

Symbol, . . . . .	I.
Equivalent, . . . . .	126.36
100 cubic inches (vapour) weigh, . . . . .	269.86
Specific gravity (vapour), . . . . .	8.70
Volume, . . . . .	100.
Specific gravity (of solid), . . . . .	4.94

Iodine was accidentally discovered in 1812, by observing that the iron vessels in which the liquors of soda ashes were being evaporated were corroded. It exists in all marine plants, in oysters, sponges, &c. It is found also in brine springs in connexion with magnesium. The residual waters of salt springs, when they are evaporated, and the salt has crystallized out, are called bittern waters. It is in these the iodine exists in combination with a metal, and from these it is obtained. It is also got from the impure carbonate of soda, called kelp, which is the ashes of sea-weeds; after the carbonate of soda is crystallized out, the iodine remains combined with sodium or potassium.

The process is precisely that for getting chlorine. Sulphuric acid and water are added to the solution of iodide of sodium or whatever metal it is united with; sulphate of soda is formed along with hydriodic acid. Bioxide of manganese is then added to this, in the proportion of one equivalent of the bioxide to two of hydriodic acid; an interchange of elements takes place, resulting in the production of one equivalent of iodide of manganese, two equivalents of water, and one equivalent of iodine. The process should be conducted in a leaden retort.



The iodine comes over in the form of a vapour, which, however, soon condenses in scales of a bluish-black colour and a metallic lustre. They are soft, friable, and opaque. Sp. gr. 4·94. Iodine melts at 225° F., and boils at 347°, giving off beautiful violet vapours; hence the name (from *ἰώδης*, violet). It is also dissipated at common temperatures. Its vapour is very dense, the specific gravity of which is 8·70.

Iodine may be brought to a spheroidal state, and it will give off no vapour in this condition until it cools down; this is true of all bodies capable of fusion.

Iodine is sparingly soluble in water, requiring 7000 times its weight; it is soluble in alcohol, ether, and the alkalies.

Iodine has the same habitudes that chlorine has, and almost as wide a range of affinities.

*Tests.*—The colour of the vapour of iodine is a tolerable test. Starch in solution gives with it a beautiful blue precipitate, the iodide of starch; the solution of starch, however, must be cold, because the iodide of starch is colourless at high temperatures, and again the iodine must be free, or if combined it may be freed by a strong acid or by chlorine. An absolute test for the presence of iodine is the bichloride of palladium, with which it gives a dark brown precipitate.

Iodine and all the other halogen bodies are separated from their compounds by chlorine, which is preferred before all the others.

#### HYDRIODIC ACID.

Formula, . . . . .	HI.
Equivalent, . . . . .	127·36
100 cubic inches weigh, . . . . .	136·
Specific gravity, . . . . .	4·40
Volume, . . . . .	100·

This compound may be formed by a direct union of the

elements by aid of a red heat. It is also prepared by mixing iodine, phosphorus, and water in a retort and applying a gentle heat; a periodide of phosphorus is first formed, then the water is decomposed, its hydrogen going to the iodine, and its oxygen to the phosphorus, forming iodohydric and phosphoric acids.

Hydriodic acid gas is colourless, has a sour taste, fumes, and has an odour similar to chlorohydric acid. It resembles the last-named acid in all its reactions.

A solution of this acid is readily obtained by passing a stream of sulphuretted hydrogen through water having iodine in fine powder suspended in it. The sulphuretted hydrogen is decomposed, its hydrogen goes to the iodine, forming hydriodic acid, which remains in solution, and its sulphur is precipitated. This solution is hard to keep, owing to the oxygen of the air uniting with the hydrogen and setting the iodine free.

#### V. BROMINE.

Symbol, . . . . .	Br.
Equivalent, . . . . .	78.26
Specific gravity (liquid), . . . . .	3.
Specific gravity (vapour), . . . . .	5.39

Bromine was discovered in 1826. It differs somewhat from iodine, but it is found under the same circumstances. It is called bromine, from *βρωμος*, strong odour.

It is obtained from bittern, by the mere addition of chlorine, which displaces it, as well as iodine, from its compounds; by applying heat, it then passes off in the form of a vapour, which condenses in drops.

Bromine is a brown liquid, of intense colour, very volatile, freezes at  $-4^{\circ}$  F., and boils at  $116^{\circ}$ . It has a hyacinthine red hue by transmitted light, but its vapour is orange red.



It is soluble in water, alcohol, and ether; the last is its best solvent and enables us to separate it from iodine.

It forms analogous compounds to those of chlorine and iodine, called bromides. It is a supporter of combustion, stains animal tissues like iodine, and is very destructive to animal life. With water bromine forms a crystalline hydrate, at 32° F.

*Hydrobromic Acid*.—This acid may be prepared, like hydriodic acid, with phosphorus. It is colourless, has an acid, pungent odour, but is of little importance.

#### COMPOUNDS OF CHLORINE, IODINE, AND BROMINE WITH OXYGEN.

Chlorine, bromine, and iodine, have but a very feeble affinity for oxygen, although their affinities for other simple elements are very great; when oxygen is presented to them, however, in its nascent condition, they may be made to combine with it.

The leading characters of these compounds are derived from the fact of the feeble affinity of the elements for each other.

#### COMPOUNDS OF CHLORINE WITH OXYGEN.

			Formula.	Chlor.	Oxyg.	Equiv.
Hypochlorous Acid,	.	.	ClO	35.41	+	8=43.41
Hypochloric Acid,	.	.	ClO <sub>2</sub>	35.41	+	32=67.41
Chloric Acid,	.	.	ClO <sub>3</sub>	35.41	+	40=75.41
Perchloric Acid	.	.	ClO <sub>4</sub>	35.41	+	56=91.41

*Hypochlorous Acid*.—Formula, ClO; equivalent 43.41. When chlorine is passed into a solution containing an oxide of a metal, both the water and the oxide are decomposed, and a chloride of the metal and hypochlorous acid are produced. If the bioxide of mercury is presented in a glass tube to a stream of chlorine gas, the protochloride of mercury and hypochlorous acid are formed.

It is a yellow, gaseous body, soluble in water, and explodes violently at  $212^{\circ}$ ; the products of the explosion are chlorine and oxygen. It bleaches powerfully, and combines with bases forming hypochlorites. The hypochlorites of the alkalis are bleaching salts.

*Hypochloric Acid.*— $\text{ClO}_4$ ; equivalent 67.41. This acid is made by acting on chlorate of potassa with sulphuric acid in a glass retort, and applying a gentle heat. The sulphuric acid decomposes some of the chlorate of potassa by removing its base; the acid is then decomposed immediately into hypochloric acid, and some of the oxygen set free goes to some chloric acid, and converts it into perchloric acid. Three equivalents of chloric acid are converted into two equivalents of hypochloric, and one equivalent of perchloric acid. By symbols  $3(\text{ClO}_5) = 2\text{ClO}_4$  and  $\text{ClO}_7$ .

The gas is of a deep yellow colour, and should be collected over mercury. It is very explosive, resolving itself into chlorine and oxygen. It is soluble in water, and the solution bleaches. It forms salts with the alkalies.

*Chloric Acid.*—Formula,  $\text{ClO}_5$ ; equivalent 75.41. When chlorine is passed through a solution of potassa in water, it is absorbed, and two salts are formed, one of which is precipitated, while the other remains in solution; the precipitate is the chlorate of potassa, in the form of flat, tabular, colourless crystals. Chloride of potassium remains in solution. The following is the reaction:—6 equivalents of chlorine act on 6 equivalents of potassa, giving 5 equivalents of chloride of potassium and 1 equivalent of chlorate of potassa. By symbols,  $6\text{Cl}$  and  $6\text{KO}$  give  $5\text{ClK}$  and  $\text{ClO}_5\text{KO}$ .

The acid may be obtained free, by substituting baryta for potassa, and then removing the baryta by sulphuric acid. It is obtained thus in the form of a thick liquid, very easily decomposed, resolving itself into hypochloric and perchloric

acids. It sets fire to paper, &c., by the facility with which it yields up oxygen. Its salts are called chlorates; they all deflagrate violently by being thrown on fire, yielding up all their oxygen and forming chlorides.

*Perchloric Acid*.—Formula,  $\text{ClO}_7$ ; equivalent 91.41. This acid is formed by the addition of sulphuric acid to the chlorate of potassa. It remains in the retort as a perchlorate of potassa; from this it is obtained by sulphuric acid. It is a colourless liquid, and it is the most stable compound of chlorine and oxygen. This fact is opposed to the great law that the *greater the number of equivalents, the more unstable the compound*.

## COMPOUNDS OF IODINE WITH OXYGEN.

	Formula.	Iodine.	Oxygen.	Equiv.
Iodic Acid, . . . . .	$\text{IO}_5$	126.36	+40	=166.36
Periodic Acid, . . . . .	$\text{IO}_7$	126.36	+56	=182.36

*Iodic Acid*.—Formula  $\text{IO}_5$ ; equivalent 166.36. This compound is prepared by the oxidation of iodine by means of nitric acid and heat. It is soluble in water, and crystallizes from its solution. Its salts are called iodates: they resemble the chlorates.

*Periodic Acid*.—Formula,  $\text{IO}_7$ ; equivalent 182.36. This is prepared by transmitting a current of chlorine gas through a solution of iodate of soda and caustic soda; chloride of sodium is formed and remains in solution, and a periodate of soda precipitated. The latter is converted into a silver salt, and the silver is then removed. The acid is got in crystals, which are permanent in the air.

## COMPOUNDS OF BROMINE WITH OXYGEN.

*Bromic Acid*.— $\text{BrO}_5$ ,  $78.26 + 40 = 118.26$ .

This is got by passing bromine through a solution of a

caustic alkali; a bromide of the metal is formed, which remains in solution, and a bromate of the alkali is precipitated.

Bromic acid is got from the bromate of baryta, prepared as above, by removing the baryta by sulphuric acid.

The two other halogen bodies, fluorine and cyanogen, will be better understood hereafter; the former, when silicon is treated of, and the latter, after nitrogen and carbon are disposed of.

## VI. NITROGEN.

Symbol,	.	.	.	.	.	.	.	N.
Equivalent,	.	.	.	.	.	.	.	14.06
100 cubic inches weigh,	.	.	.	.	.	.	.	30.14
Specific gravity,	.	.	.	.	.	.	.	.972
Volume,	.	.	.	.	.	.	.	100

Nitrogen was discovered in 1772, by Dr. Rutherford, of Edinburgh. It was called nitrogen because it is an essential constituent of nitric acid.

Nitrogen is readily obtained from the air, in which it exists (combined mechanically with oxygen), by placing a piece of burning phosphorus in a jar of air inverted over water. The phosphorus continues burning, until all the oxygen in the jar is consumed; phosphoric acid is formed, which is dissolved out by the water, and nitrogen remains in the jar. Got in this way, it is impure. It may also be got from the muscles of animals, by acting on them with nitric acid. To get it pure, pass a current of chlorine through a solution of ammonia, which is a compound of nitrogen and hydrogen; a chloride of hydrogen is formed, and nitrogen is set free.

Nitrogen is a colourless gas, devoid of smell or taste. It does not change vegetable blues, and it is distinguished alto-

gether by its negative characteristics. It is a non-combustible, a non-supporter of combustion, and will not support animal life. It is not absorbed by water. 100 cubic inches weigh 30·14; it is 14 times heavier than hydrogen, hence its equivalent is 14·06.

Nitrogen constitutes  $\frac{4}{5}$  of the atmosphere and enters into many affinities.

## ATMOSPHERIC AIR.

The earth is everywhere surrounded by a gaseous matter, called the atmosphere, which is colourless, elastic, invisible, has neither smell nor taste, and excites no sense of touch, unless it is in motion. Its specific gravity is taken as unity, being the standard of comparison for other airs or gases. It is 815 lighter than water, and 100 cubic inches weigh 31·012. Its physical constitution has, however, been treated of before.

One of the most important constituents of the air is nitrogen; this is associated with oxygen and certain other substances, viz., moisture, which varies as the temperature, carbonic acid, which is also continually fluctuating, and ammonia.

Its constitution, both by volume and weight, may be seen by the table.

## CONSTITUTION OF AIR BY VOLUME AND WEIGHT.

By Volume.		By Weight.	
Oxygen, . . .	20·800	Oxygen, . . .	23
Nitrogen, . . .	79·190	Nitrogen . . .	76
Carbonic Acid,	0·005	Carbonic Acid,	
Ammonia, and Wa-		Ammonia, and	
tery Vapour,	·005	Watery Vapour,	1
	<hr/>		<hr/>
	100·00		100

Air is not a chemical compound of oxygen and nitrogen,

but the gases are mixed mechanically by their power of diffusibility.

The quantity of oxygen, which was supposed at one time to be invariably the same, fluctuates every hour in the day; the mean, however, is what is stated in the table, 20·8 per cent.

The amount of oxygen in the air is readily measured by exploding hydrogen gas in a confined portion of air. An instrument constructed for this purpose, is called a eudiometer. It is found by it that, by taking 100 measures of air, and then adding 40 measures of hydrogen, making in all 140 measures, and exploding by means of an electric spark, that only 80 measures will be left after the explosion. Hence, the inference is, that of the 60 measures that disappeared, 20 were oxygen, which united to 40 of hydrogen, forming water. Therefore 100 volumes of air contain 20 per cent. or  $\frac{1}{5}$  of its bulk of oxygen.

#### COMPOUNDS OF NITROGEN WITH OXYGEN.

	By volume.		By weight.	Equiv.	Symbols.
	N.	O.			
Nitrous Oxide,	100	50	14·06+8	=22·04	NO
Nitric Oxide,	100	100	14·06+16	=30·04	NO <sub>2</sub>
Hyponitrous Acid,	100	150	14·06+24	=38·04	NO <sub>2</sub>
Nitrous Acid,	100	200	14·06+32	=46·04	NO <sub>2</sub>
Nitric Acid,	100	250	14·06+40	=54·04	NO <sub>5</sub>

It is necessary to understand nitric acid previous to studying the other compounds of nitrogen with oxygen.

*Nitric Acid.*—Formula, NO<sub>5</sub>; equivalent, 54·04; specific gravity, 1·5.

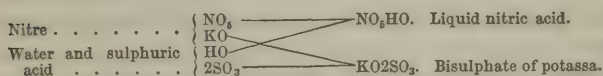
Nitric acid may be prepared by passing a succession of electric sparks through a mixture of nitrogen and oxygen gases. It is also evolved by the spontaneous decomposition of organic matter when moisture is present, and an alkali or base to unite with the acid. It occurs in this way in India



and many other places. The base is generally lime or potassa, forming the nitrate of lime or potassa. The last salt is the nitre or saltpetre of commerce.

The above natural process is now artificially imitated in France and Germany; it will be detailed under the salts.

Nitric acid is readily obtained from nitrate of potash by adding two parts by weight of sulphuric acid to one of the nitre, and applying heat. Nitric acid is distilled over from the retort, and a bisulphate of potassa remains.



The acid as it passes over unites with the vapour of water and condenses. It cannot exist as an *acid* without water; but it has lately been isolated in a dry crystalline form. In this way it exerts no acid reactions; they are only developed by water.

Pure nitric acid is colourless, but that of commerce, called aqua fortis, is very impure. Its yellow colour is due to the presence of hyponitrous acid. It also contains salts of iron, sulphuric acid, chlorohydric acid, &c. The sulphuric acid may be removed by baryta, and the chlorohydric acid by a salt of silver. The strongest nitric acid contains but one equivalent of water; its specific gravity is 1.52.

TABLE OF DIFFERENT KINDS OF NITRIC ACID.

Nitric acid of sp. gr. 1.52— $\text{NO}_3 + \text{HO}$ , 14 per cent. of water.					
“	“	1.50— $\text{NO}_3 + 3\text{HO}$ ,	20	“	“
“	“	1.42— $\text{NO}_3 + 4\text{HO}$ ,	40	“	“

When nitric acid boils, which it does at  $248^\circ$ , it contains exactly 4 equivalents of water, and then has a sp. gr. of 1.42. By boiling strong acid, it becomes weaker, and weaker acid

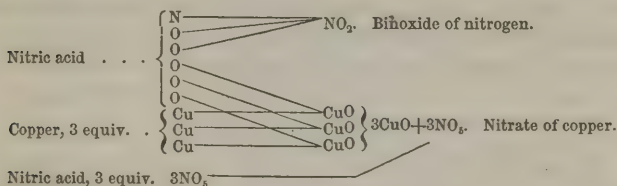


one volume of nitrogen and  $\frac{1}{2}$  volume of oxygen, condensed into one volume.

Its constitution is determined by exploding one volume of it with one of hydrogen: water is formed and 1 measure of nitrogen remains.

*Binoxide of Nitrogen; Nitric Oxide.*—Equivalent, 30.04; formula,  $\text{NO}_2$ ; specific gravity, 1.039. 100 cubic inches weigh 32.22 grains; volume, 200.

This gas is best obtained by the action of nitric acid on copper or mercury. Part of the acid is decomposed, the metal oxidized, three equivalents of oxygen are removed, and two are left in combination with nitrogen. The undecomposed acid unites with the oxide of the metal, forming a nitrate,—if copper is used, a nitrate of the oxide of copper,—while the gas is given off.



This is a colourless gas, heavier than air, 100 cubic inches weighing 32.22 grains. It is composed of one volume of nitrogen and one volume of oxygen, without condensation. It has a very strong affinity for oxygen, and always seizes it, when it meets it in an uncombined state, forming beautiful orange-coloured fumes, which serve as a test for free oxygen and nitric acid, through the medium of copper.

*Hyponitrous Acid.*—Formula,  $\text{NO}_2$ ; equivalent, 38.04; specific gravity (of gas), 1.72.

When nitric oxide in excess meets atmospheric air or oxygen, it is converted into hyponitrous acid, by taking one more equivalent of oxygen. It is condensed into a thin,

colourless, mobile liquid at  $0^{\circ}$  F. This liquid is green at common temperatures, and flies off in orange-coloured vapours by heat.

Hyponitrous acid is decomposed by water, being resolved into nitric oxide and nitric acid.

Thus,  $3\text{NO}_3$  and  $\text{HO}=\text{NO}_5$  and  $2\text{NO}_2$ . The acid is absorbed by the water, while the oxide remains as such till it meets a new portion of air.

*Nitrous Acid*.—Formula,  $\text{NO}_4$ ; equivalent, 46.04; specific gravity (of gas), 3.18; (of liquid), 1.45.

Nitrous acid is always formed when nitric oxide escapes in the open air; deep red fumes are the result, which are only the vapour of nitrous acid, and are condensable in a liquid.

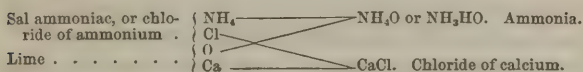
This acid is yellow at common temperatures, but becomes reddish as the temperature rises. It boils at  $82^{\circ}$ , giving off red vapours. It is absorbed by water and converted into nitric acid and nitric oxide; the latter escapes with effervescence. Thus  $3\text{NO}_4$  yield  $2\text{NO}_5$  and  $\text{NO}_2$ .

#### NITROGEN AND HYDROGEN.

*Ammonia*.—Formula,  $\text{NH}_3+\text{HO}$  or  $\text{NH}_4\text{O}$ ; equivalent, 26.06. 100 cubic inches (gas) weigh 18.26 grains; specific gravity, .589.

This substance was obtained originally near the Temple of Jupiter Ammon, hence the name. It is composed of nitrogen and hydrogen, and may be formed by passing an electric spark through a mixture of the two gases. It occurs spontaneously during the putrefaction of nitrogenized bodies. It is also obtained as a product after the distillation of coal to produce coal gas, and most of the ammonia used is obtained from that source. The most convenient method is to decompose one of its salts; for this purpose the chloride of ammonium (sal ammoniac) is used. This is placed in a retort and quicklime added; heat is then applied; a decomposition takes

place, and chloride of calcium is formed while ammonia is given off.



The gas is colourless, has a pungent odour and a strong alkaline reaction. It is condensed into a liquid by a pressure of 6·5 atmospheres at 60° F. Water absorbs 700 times its bulk of it, forming a solution called *liquor ammoniæ*, the density of which is about ·875. So powerful is the affinity of water for ammonia, that if a vessel containing ammoniacal gas be inverted over water, the latter will rush up and fill the whole space, as if it were a vacuum.

Ammonia forms salts and confers its volatility on all of them. With iodine, chlorine, &c., it forms very explosive compounds, which are chlorides and iodides of nitrogen, &c.

It is composed of one volume of nitrogen and three volumes of hydrogen condensed into two volumes.

*Tests.*—Its presence is detected by its odour, by its action on turmeric paper, and by forming dense white clouds with chlorohydric acid gas.

*Constitution of Ammonia.*—Chemistry reveals to us three compounds of nitrogen and hydrogen, viz. :

	Nitrogen.	Hydrogen.	
Amidogen, . . .	N	+ 2H or NH.	Symbol Ad.
Ammonia, . . .	N	+ 3H or NH <sub>3</sub> .	Formula Ad+H.
Ammonium, . . .	N	+ 4H or NH <sub>4</sub> .	“ Ad+2H.

The substance called ammonia which we usually see is not ammonia, because this, which is 1 equivalent of nitrogen, and 3 equivalents of hydrogen, exists only when the dry gases are

mixed, made to combine, and then kept out of contact with water or moisture. There is always water present in common ammonia, and when this is the case a new arrangement takes place, viz., the oxide of a hypothetical metal is formed.

Thus, add water to ammonia, and there is got  $\text{NH}_3 + \text{HO}$ , which is equivalent to  $\text{NH}_4 + \text{O}$ . The  $\text{NH}_4$  is the radical, and an oxide of this radical makes the base. The proofs advanced for the above opinion are, that it forms salts with oxy-acids, and no oxy-acid can or will unite with a base that does not contain oxygen. Thus, sulphuric acid will not unite with zinc, but only with its oxide; hence the inference that ammonia is the oxide of ammonium. Again, an amalgam can be formed with ammonia (an amalgam is a semi-solid formed by the union of mercury with a metal); hence the inference that it is a kind of a metal, because nothing but metals form amalgams. This very curious compound may be made by first forming an amalgam with sodium; then adding to this the chloride of ammonium (sal ammonia). The chlorine has a stronger affinity for the sodium than for the ammonium; it therefore takes it from the mercury: the ammonium, being thus freed, then unites with the mercury, forming ammoniacal amalgam. This amalgam may also be formed by the decomposition of ammonia by a battery, and evolving oxygen at the positive pole, while ammonium is being evolved at the negative one, in contact with mercury. Ammoniacal amalgam is soft, porous, very light, and very volatile, giving off ammonia rapidly. It is soon resolved into its constituents, and mercury only remains.

From the above facts it is safe to conclude that there is a hypothetical metal called ammonium, whose formula would be  $\text{NH}_4$ , and that of its oxide  $\text{NH}_4 + \text{O}$ ; equivalent,  $18 + 8 = 26$ .

*Amidogen*.—Symbol Ad, or  $\text{NH}_2$ ; equivalent 16.



When ammonia is added to a solution of the bichloride of mercury (corrosive sublimate), a precipitate results, which is a double salt, viz., the bichloride, in combination with the biamide of mercury; that is, the ammonia is decomposed and converted into amidogen, which then unites with some mercury. The formula of the salt is  $\text{HgAd}_2 + \text{HgCl}_2$ ; the reaction will be seen under the head of double salts of mercury. Amidogen is thus demonstrated, but it has never been isolated.

## VII. CARBON.

Symbol, . . . . .	C
Equivalent, . . . . .	6
Specific gravity of vapour (hypothetical),	0.4215
100 cubic inches weigh, . . . . .	13 grains.
Volume, . . . . .	100.

Carbon, the basis of all organic nature, is found in all organized bodies; these yield it when charred. Carbon is got under a great variety of forms; the purest is the diamond. This gem is found only in secondary formations, and seems to have been developed from organic bodies. India, Borneo, and Brazil furnish most of them. It is of adamantine hardness, which is its most valuable property, very transparent and colourless, and it crystallizes in regular octohedrons, the sides of which are sometimes rounded, sometimes plane. It bears intense heat without burning or fusion, if atmospheric air or oxygen be excluded, but in the presence of these it burns readily, yielding carbonic acid gas. The diamond is one distinct crystalline form of carbon; the other form is graphite (plumbago or black lead). The latter contains iron, varying from a trace to 5 per cent.; it is rare, the purest being found in England. When it crystallizes, it is

in the form of a six-sided prism. Carbon is therefore said to be diamorphous, that is, it has two crystalline forms. Carbon is also got as charcoal, coke, ivory black, lampblack, &c., all these being the uncrystallized form of it.

Charcoal, coke, &c., are obtained from their respective sources, by heating in vessels excluding atmospheric air.

Charcoal possesses the property of absorbing large quantities of air and gases at common temperatures, and yielding them again by heat. Charcoal prepared from box-wood, possesses this property in the most remarkable degree. It absorbs 90 times its volume of ammoniacal gas, 85 times its volume of chlorohydric acid gas, &c. This property is attributed to the porosity of the coal; because it is nearly destroyed by reducing the coal to powder.

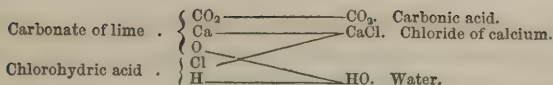
#### COMPOUNDS OF CARBON WITH OXYGEN.

	Carbon.	Oxygen.	Equiv.	Formula.
Carbonic oxide	. 6 or 1 eq. +	8 or 1 eq. =	14	CO
Carbonic acid	. 6 or 1 eq. +	16 or 2 eq. =	22	CO <sub>2</sub>

*Carbonic Acid.*—Formula CO<sub>2</sub>; equivalent 22; 100 cubic inches weigh 47·26 grains; specific gravity 1·52; volume 100.

When carbon burns in the open air or in oxygen gas, the product of the combustion is carbonic acid gas; it is conveniently prepared, however, from a carbonate. Fragments of marble or clam-shells or chalk, all of which are carbonate of lime, may be conveniently used, and to any one of these chlorohydric acid is added in a glass vessel or a retort; the gas then escapes with effervescence.

The following is the reaction: the chlorine of the acid unites with the base of the lime, forming chloride of calcium, its oxygen at the same time uniting with the hydrogen of the acid, forming water, while the carbonic acid which is freed escapes.



The gas may be collected over water, or in a jar of air, which it will displace.

Carbonic acid gas is colourless, and of an agreeable pungent taste and odour. It is elastic, requiring a pressure of 36 atmospheres to condense it into a fluid. It is very heavy; 100 cubic inches weigh 47·26 grains: hence its density is 1·52. It may be poured from one vessel to another.

Carbonic acid gas is incombustible, and a non-supporter of combustion or respiration.

When inhaled, as is frequently done from coal fires in close rooms, it produces asphyxia, by the blood in the lungs not being oxygenated.

Carbonic acid is sometimes emitted in large quantities from the earth, and is constantly produced by the fermenting of organic matter. When it accumulates in the bottoms of old wells and such places, it is called *choke-damp*. In the Grotto del Cane, in Italy, it issues from the ground.

Carbonic acid exists in the air diffused throughout its whole extent, and, although the percentage is very small, being only ·004 or 005, yet, if it were all collected, it would form a stratum around the surface of the globe 16 feet in depth.

By heating carbonic acid with something having a very powerful affinity for oxygen, as potassium, the acid is decomposed, and a precipitate of solid carbon takes place from the gas; this proves analytically the constitution of carbonic acid gas.

Ordinary water owes its taste to carbonic acid, and many mineral waters are rendered such by its presence. Artificial mineral waters are water saturated with carbonic acid.

The solution of carbonic acid in water forms one of the great solvents of nature, and it is by means of it that rocks are disintegrated and converted into soils.

The salts of carbonic acid are numerous; they are carbonates. Marble is a carbonate of lime in the crystalline form; it is primary, and differs much from limestone soils, which are organic, deriving their acid from organic growths.

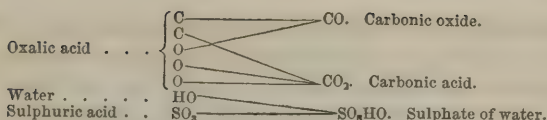
*Test.*—The test for carbonic acid is lime-water, which becomes turbid when a stream of the acid is passed through it, owing to the precipitation of carbonate of lime; this precipitate is, however, redissolved by an excess of the acid. Saratoga water is of this description; it contains a great excess of carbonic acid, and by this means the carbonates of lime and magnesia are held in solution.

*Carbonic Oxide.*—Formula, CO; equivalent, 14; 100 cubic inches weigh 30.21 grains; specific gravity .973; volume 100.

Present carbonic acid to red hot charcoal, or metallic iron, and it will lose 1 equivalent of its oxygen and be converted into carbonic oxide.

Carbonic oxide may be also made by decomposing oxalic acid by means of a stronger acid and heat.

Oxalic acid, which is carbon 2 equivalents, and oxygen 3 equivalents ( $C_2O_3$ ), cannot exist without a base, when heat is applied; and this base may be anything, as potassa, soda, or even water. It contains just the proportions for forming carbonic acid and carbonic oxide, and when it loses its base, and heat is applied, it flies off into these gases. To do this it is only necessary to add sulphuric acid, which takes away the base, and the two compounds are got in the receiver, mixed in equal proportions. The carbonic acid may then be removed by lime-water, and the carbonic oxide remains pure.



Carbonic acid can also be obtained by decomposing the ferrocyanide of potassium by five or six times its weight of sulphuric acid. The gas in all cases may be collected over water.

Carbonic oxide is a colourless gas, lighter than air, its specific gravity being .973. It has very little odour, is extremely poisonous, and has never been liquefied. It exerts no acid reactions. It is a non-supporter of combustion, but burns itself with a pale blue flame, giving very little light; this flame is often seen on the surface of coal fires, and is due in them to the same cause. When it burns it generates carbonic acid. A mixture of carbonic oxide and oxygen gases will explode; its constitution is determined in this way. Carbonic oxide contains 100 measures of carbon vapour and 50 measures of oxygen condensed into 100 measures. Carbonic acid contains 100 measures of vapour of carbon and 100 of oxygen condensed into 100 measures.

Carbonic oxide is supposed to be the basis of all the rest of the oxy-compounds of carbon.

#### CARBONIC OXIDE SERIES.

Carbonic Oxide, . . . . .	CO.
Carbonic Acid, . . . . .	CO + O.
Oxalic Acid, . . . . .	2CO + O.
Chlorocarbonic Acid (phosgene gas) . . . . .	CO + Cl.
Croconic Acid, . . . . .	5CO + H.
Mellitic Acid, . . . . .	4CO + H.
&c., &c.	

#### COMPOUNDS OF CARBON WITH HYDROGEN, CARBO-HYDROGENS.

There are an immense number of compounds of hydrogen

and carbon; many of these have the same constituents in the same proportion, yet differ very materially in constitution; they are called *isomeric bodies*. Sugar, gum, and starch, are of this character. This subject also includes the fats, essential oils, &c., &c., but it more properly belongs to organic chemistry. Under the present head will be treated light carburetted hydrogen, and olefiant gas.

*Light Carburetted Hydrogen*.—Formula,  $\text{CH}_2$ ; equivalent, 8; 100 cubic inches weigh 17.41 grains; specific gravity, .559.

Carbon presented to hydrogen directly will not unite with it under any circumstances, but there are very many compounds of carbon and hydrogen which are the result of vital and organic processes; from these it may be got.

It is abundantly elicited in coal mines; there it is called fire-damp, and when emitted from apertures, the jet is called a blower.

The mud at the bottom of muddy pools and marshes, on being stirred, permits a gas to escape, which is a mixture of light carburetted hydrogen and carbonic acid; the latter is removed by lime-water; hence the present compound is sometimes called marsh gas. It is obtained artificially by heating acetate of soda, quicklime, and hydrate of potash in a glass retort; the acetic acid is decomposed into 2 equivalents of carbonic acid and 2 equivalents of carburetted hydrogen.

Light carburetted hydrogen is colourless and nearly inodorous. It is a non-supporter of combustion, but burns itself with a yellow flame, emitting much light. It detonates when mixed with oxygen. It is composed of one volume of vapour of carbon and two volumes of hydrogen condensed into one. It is half as heavy as air. Coal gas for street-lighting is a mixture of this and some other gases.

*Olefiant Gas*.—Formula,  $\text{C}_2\text{H}_2$ ; equivalent, 14; 100



cubic inches weigh 30·57 grains; specific gravity, ·980; volume 100.

Olefiant gas is best prepared by mixing alcohol with six times its weight of sulphuric acid in a glass retort, and applying heat; the gas comes over, and may be collected over water or mercury. The reactions are too complex to be understood now, but for the sake of convenience alcohol may be considered a mixture of olefiant gas and water, and the acid removes the latter.

It is colourless, tasteless, inodorous, extinguishes flame, but burns itself with a dense, white light; the products of its combustion are carbonic acid and water. With the proper mixture of oxygen, it detonates violently. It consists of 2 volumes of vapour of carbon and 2 volumes of hydrogen condensed into 1 volume.

Chlorine acts powerfully on this gas. When the gases are mixed and allowed to remain at rest, a union takes place between them, producing an oil-like liquid, from which the name olefiant gas is derived. This liquid is called the chloride of hydrocarbon, sometimes *Dutch liquid*.

The gas used for street-lighting, obtained from coal, contains much olefiant gas, and also carburetted hydrogen; it is got by submitting bituminous coal to destructive distillation in iron retorts. The products are hydrocarburets, volatile oils, nitrogen, ammonia, carbonic acid, &c.

The light given off by burning gases bears a proportion to their specific gravities.

#### CONSTITUTION OF FLAME.

Flame is gas heated to a white heat. On holding a piece of porcelain down on the flame of a burning hydrocarburet, a black stain is left; this is carbon, which is deposited in an unburned condition. The solid particles of the carbon be-

come white hot without being burned, because there is not sufficient oxygen to consume them, and by this means an intense light is obtained.

This is readily proved by passing a stream of air through the flame by means of a blowpipe. A large quantity of oxygen is thus supplied, and all the matter in the flame is burned, provided it be combustible, and no light is given off.

When a tube is presented to flame, or a ring held over it, the flame is put out. This experiment may be readily performed with a candle, by holding a small ring over it in such a way, as to just encircle the flame; the candle will be put out, although the wick be not touched. The reason of the candle being put out is because the metallic ring is such a rapid conductor of heat, that it reduces the temperature of the gas below whiteness, and consequently there is no more flame.

Flame is, as has been said, only the ignition of gaseous matter; and as combustion can only take place in contact with oxygen, flame must, therefore, be hollow: this is really the case. Flame is composed of 3 parts: an inside dark part, outside of that a luminous one, generally yellow, and outside of this a colourless portion, where all the combustible material is consumed, because it is in contact with the oxygen of the air; it is, therefore, the hottest portion. Flame is also always pinched in at the top by air rushing in to supply the vacuum created by the rise of the heated air: this thus constitutes a continuous current from below upwards.

Flame, it has already been said, cannot pass through metallic rings or tubes without having its temperature so reduced by the great conducting power of the metallic ring, that it will be flame no longer. Sir Humphry Davy inferred from this that flame could not pass through fine gauze wire, which is a succession of many small rings. This, on experiment proved true; and he therefore constructed his safety

lamp for mines. This is nothing more than a common lamp, surrounded completely by fine gauze wire: the wires present a large surface, are good conductors, and reduce the temperature inside below that of flame, and consequently explosive mixtures cannot be fired by a flame thus surrounded.

#### COMPOUNDS OF CARBON AND NITROGEN.

*Cyanogen, or Bicarburet of Nitrogen.*—Formula,  $\text{NC}_2$  or Cy; equivalent,  $14+12=26$ ; 100 cubic inches weigh 56.30 grains; specific gravity, 1.81; volume 100.

Carbon will not combine directly with nitrogen, but when a nitrogenized body is heated in the air, in contact with an alkali, its nitrogen unites with its carbon, to form cyanogen, and this unites with the alkali present, forming a cyanide.

Cyanogen is obtained indirectly by first heating Prussian blue with the bioxide of mercury: this gives the bicyanide of mercury; the iron of the Prussian blue (which is the ferrocyanide of iron) takes the oxygen of the mercury, and the latter then takes the cyanogen. If the bicyanide of mercury is now heated, the cyanogen is obtained free.

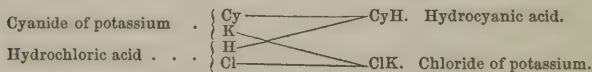
Cyanogen is a colourless gas, having the odour of peach-blossoms. At the temperature of  $45^\circ$  Fahrenheit, and under a pressure of  $3\frac{1}{2}$  atmospheres, it becomes a limpid liquid, which again becomes gaseous, as soon as the pressure is removed. It is a non-supporter of combustion, but burns itself with a beautiful roseate flame; the products of its combustion are carbonic acid and nitrogen. It can thus be analyzed: Take 100 cubic inches of cyanogen and burn it with 200 cubic inches of oxygen; as a result we get 200 cubic inches of carbonic acid gas and 100 of nitrogen; proving that 2 equivalents of carbon were united to one of nitrogen, because

carbonic acid contains 1 volume of oxygen (or 2 equivalents) and 1 volume of carbon condensed into 1 volume.

Its weight is nearly twice that of air, being 1.810. Cyanogen is a halogen body resembling chlorine; hence there is a cyanide for every chloride. It is also a compound body; but it performs the functions of a simple one, and is, therefore, called a compound radical; further, it is the only compound radical that has ever been isolated excepting kakodyle.

*Cyanhydric Acid or Hydrocyanic or Prussic Acid.*—Formula,  $C_2NH$  or  $CyH$ ; equivalent,  $26+1=27$ ; specific gravity (liquid), 0.6767.

Cyanogen will unite with hydrogen under precisely the same circumstances that chlorine does. Thus, present sulphuric acid or muriatic acid to the cyanide of potassium, and hydrocyanic acid will escape. If muriatic acid is used, its chlorine unites with the base, while the cyanogen unites with the hydrogen.



It is obtained in the form of a gas, which is the most poisonous body in nature. If the gas be dried, by passing it through chloride of calcium, and received in a cool vessel, it will be condensed as liquid, anhydrous, hydrocyanic acid.

This body is a thin, colourless, and exceedingly volatile liquid, which has a density of .6767 at  $45^\circ$ , boils at  $79^\circ$ , and freezes at  $0^\circ$ ; its odour is very powerful, resembling that of peach-blossoms; it has a feeble acid reaction, and is soluble in water in all proportions. It is one of the most fearful poisons in nature; but it is employed in medicine in minute doses, the medicinal acid containing only 2 per cent. of the real acid. The strong acid is so volatile that it freezes by its own evaporation, which takes place at  $80^\circ$  Fahrenheit. With water it is decomposed into formic acid and ammonia.

This it is important for the physician to know. It may be detected by holding it over the fumes of muriatic acid; if a white cloud forms (chloride of ammonium), it contains ammonia. Prussic acid may be got from bitter almonds by distillation with water.

*Cyanic Acid.* Formula  $C_2NO$ , or  $CyO$ ; equivalent 34.

When the cyanide of potassium is heated in the air, the cyanogen and potassium both take oxygen from the air, and a cyanate of potassa is formed ( $CyO$ ,  $KO$ ). The potassa may be removed and the cyanic acid left in combination with water. It is a limpid, colourless liquid, with a pungent odour, like strong acetic acid. Cyanic acid is analogous to many other compounds of carbon, nitrogen, and oxygen, which are said to be isomeric with it.

*Cyanate of Ammonia.*—This is a compound, only interesting because it is isomeric with *urea*, one of the organic constituents of the urine. It is made by heating the vapour of cyanic acid in contact with ammoniacal gas in excess, or by mixing one part of cyanate of potassa with two parts of sulphate of ammonia; a double decomposition results when heat is applied, and white crystalline cyanate of ammonia is obtained. Its formula is  $CyO$ ,  $NH_3 + HO$ , or  $C_2NO$ ,  $NH_4 + O$ , which is equal to 2 equivalents of carbon, 2 equivalents of nitrogen, 4 equivalents of hydrogen, and 2 equivalents of oxygen,—thus corresponding exactly with the formula for *urea*,  $C_2N_2H_4O_2$ .

*Fulminic Acid.*—Formula  $Cy_2O_2$ ; equivalent 68.

This acid is developed by the action of hyponitrous acid on alcohol in the presence of a salt, which may be either silver or mercury. It has never been isolated.

The *fulminate of silver* is prepared by adding silver to nitric acid, and when the silver is dissolved, adding alcohol. The latter is oxidized, by the acid being converted into aldehyde and oxalic acid, while the nitric acid is converted into

hyponitrous acid; this then reacts on some undecomposed alcohol, forming hyponitrous ether, water, and fulminic acid. The fulminic acid thus developed now unites with the oxide of silver, which crystallizes out in small white plates. The fulminate of silver is one of the most violent explosive mixtures known to the chemist. Fulminic acid forms salts also with mercury, zinc, &c.

*Cyanuric acid* is another compound isomeric with cyanic acid. Its formula is  $Cy_3O_3$ . It does not form explosive compounds.

*Tests for Cyanogen.*—1. The odour is like peach-blossoms.

2. Hydrocyanic acid gives a white precipitate with a soluble salt of silver, which is the cyanide, and which becomes black by exposure. We must be first certain, however, that there is no chlorine or bromine present.

3. A blue precipitate is obtained by heating a compound supposed to contain cyanogen with an alkali and a persalt of iron.

4. Place the suspected fluid in a capsule over a flame, invert over it a watch-glass, moistened with a solution of the sulphuret of ammonium. The heat causes the cyanogen to rise in vapours, which seize the sulphur and form sulphocyanogen; this unites with the ammonium, and forms the sulphocyanide of ammonium. All that remains to do now, is to place a drop of a solution of a persalt of iron on this, and a blood-red spot is obtained, which is the sulphocyanide of iron.\*

#### VIII. SULPHUR.

Symbol, . . . . .	S
Equivalent, . . . . .	16
Specific gravity, . . . . .	1.98
Specific gravity (vapour), . . . . .	6.648
Combining volume, . . . . .	16.66 or $\frac{1}{2}$

\* This test is infallible.



Sulphur is an elementary body, resembling oxygen very much in its habitudes.

It is found in large quantities in Sicily, Italy, and other volcanic districts. The earth yielding it is called *sulpha terra*; this is heated, it melts at  $232^{\circ}$  F., and the sulphur is skimmed off from its impurities. This is again fused, and poured into moulds, forming roll brimstone. Sulphur is a brittle solid, always yellow when pure, emits an odour when rubbed, and has little taste. It is a non-conductor of electricity. Its specific gravity is 1.98. Heated to  $216^{\circ}$  F. it melts; at  $300^{\circ}$  it burns, uniting with the oxygen of the air; as it melts it becomes amber-coloured, and as the temperature increases it thickens. At  $400^{\circ}$  it is very inspissated, and if it be now thrown in water, it will not solidify, but remain a soft and elastic mass, called sulphur cast. Beyond  $400^{\circ}$  it again becomes very liquid, and at  $600^{\circ}$  it boils or volatilizes, and its vapour may be called sulphur gas. The density of the vapour of sulphur is 6.648, hence 100 cubic inches weigh 206.407 grains.

Sulphur has two crystalline forms, viz., the prismatic and octohedral. The prismatic form is well shown, by melting it in a crucible, and then allowing it to cool until a crust accumulates on its surface; then break this and pour out the interior fused mass, and what adheres to the sides of the crucible will crystallize beautifully. When first cooled, the crystals are transparent and amber-coloured, but by exposure they lose their transparency and crystalline form. They are at first, right rhombic prisms, but become oblique rhombic prisms.

If a metal is heated in sulphur vapour, it will burn, giving rise to a sulphuret; that is, the vapour of sulphur is a supporter of combustion, precisely as oxygen is; and when a body burns in it, a sulphuration takes place, precisely as oxidation takes place, when the same body is burned in oxygen gas.

Sulphur is an amphigen body, that is, it generates both acids and bases. Of this class oxygen is the type : thus, oxygen will unite with one body, as nitrogen, and form an oxy-acid; and again it will unite with another body, as potassium, and form an oxy-base, which base will unite as such with the oxy-acid, and the union of the two form the oxy-salt nitrate of potassa. This is true of sulphur. It combines with bodies forming sulphur acids, and with others forming sulphur bases, and the union of the two forms a sulphur salt. Thus, arsenic with oxygen forms arsenious acid ( $\text{AsO}_3$ ), which will unite with potassa ( $\text{KO}$ ), and form the arsenite of potassa ( $\text{AsO}_3 \text{ KO}$ ). We may now substitute sulphur for the oxygen in these cases; for arsenious acid we get the tersulphuret of arsenic, and the sulphuret of potassium for potassa, while the union of these two gives the sulphur salt sulpharsenite of the sulphuret of potassium ( $\text{AsS}_3 + \text{KS}$ ).

## COMPOUNDS OF SULPHUR AND OXYGEN.

	Sulphur. Oxygen. Equiv.	Formula.
Sulphurous Acid, . . .	$16 + 16 = 32$	$\text{SO}_2$ .
Sulphuric Acid, . . .	$16 + 24 = 40$	$\text{SO}_3$ or $\text{SO}_2 + \text{O}$ .
Hyposulphurous Acid, .	$32 + 16 = 48$	$\text{S}_2\text{O}_3$ or $\text{SO}_2 + \text{S}$ .
Hyposulphuric Acid, . .	$32 + 40 = 72$	$\text{S}_2\text{O}_6$ or $2(\text{SO}_3) + \text{O}$ .
&c., &c.		

Besides the above we have

Chlorosulphurous Acid, . . . . .	$\text{SO}_2 + \text{Cl}$ .
Iodosulphurous Acid, . . . . .	$\text{SO}_2 + \text{I}$ .
Nitrosulphurous Acid, . . . . .	$\text{SO}_2 + \text{NO}$ .
&c., &c.	

*Sulphurous Acid*.—Formula,  $\text{SO}_2$ ; equivalent,  $16 + 16 = 32$ . By volume, 1 vol. of oxygen and  $\frac{1}{2}$  vol. of vapour of sulphur condensed into one volume. Specific gravity 2.21.

When sulphur is burned in oxygen or the air, the result is invariably sulphurous acid. It is also very conveniently prepared for use by acting on metallic copper or mercury with sulphuric acid; the metals are oxidized, taking one equivalent of oxygen from the acid and leaving sulphurous acid. It should be collected over mercury, because water dissolves it freely.

Sulphurous acid is a gaseous body, colourless, totally irrespirable, incombustible, and does not support combustion. It exerts strong acid reactions, and is a good bleaching agent.

It is a powerful deoxidizing body on account of its great affinity for oxygen.

Sulphurous acid is condensible by  $2\frac{1}{2}$  atmospheres at  $45^{\circ}$  F., or by 1 atmosphere at  $0^{\circ}$ , into a colourless limpid liquid, which passes into gas very rapidly when heated. Water dissolves 30 times its volume of sulphurous acid.

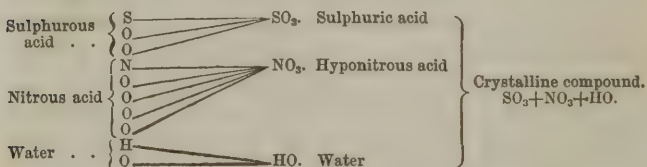
This acid forms a vast number of salts; it unites also in definite proportions with water, and forms a solid, like ice. It is the basis of all the other compounds of sulphur and oxygen.

*Sulphuric Acid*.—Formula,  $\text{SO}_3$ , or  $\text{SO}_2 + \text{O}$ . Equivalent, 40. Specific gravity, 1.85.

Sulphuric acid, or, as it was called, oil of vitriol, was discovered by Basil Valentine in the 15th century. It is obtained either by decomposing sulphate of iron (copperas), or by oxidizing sulphurous acid by means of nitrous acid; the latter is almost the only plan pursued for obtaining commercial acid. The method is as follows: A large chamber is made of sheet lead supported by timbers; at one extremity is an opening leading to a furnace in which sulphur is kept burning to manufacture sulphurous acid. The same opening also conveys nitric acid to the chamber, which acid is evolved by the action of sulphuric acid on nitrate of potassa. On the floor is a shallow stratum of water, and at the remote end of the chamber is an exit for the

useless gases. There is therefore in the chamber a constant supply of sulphurous acid, atmospheric air, nitric acid vapour, and vapour of water. The sulphurous acid now removes one equivalent of oxygen from the nitric acid, converting it into nitrous acid and itself into sulphuric acid, which is dissolved out by the water. Another portion of sulphurous acid removes another equivalent of oxygen from the nitrous acid, and converts it into hyponitrous acid. There are now in the chamber, sulphuric acid vapour, hyponitrous acid, and vapour of water, and these three bodies unite to form a crystalline compound, like snow, which falls to the bottom of the chamber. As soon as this crystalline body meets the water, the sulphuric acid is dissolved out, and the hyponitrous acid (which, as has been already shown, cannot exist as such when it meets water), is immediately converted into nitric oxide and nitric acid; the nitric acid remains in the water, while the oxide escapes with effervescence. When the nitric oxide rises in the air, it meets oxygen and is converted into nitrous acid; this nitrous acid again gives up one equivalent of oxygen to sulphurous acid, which is converted into sulphuric acid, and this again unites with the hyponitrous acid and vapour of water to form the crystalline compound, which falls into the water at the bottom of the chamber to be again decomposed.

In the diagram are the ingredients and their manner of uniting to form the crystalline compound.



The process detailed above is continued until the water is sufficiently charged with sulphuric acid, when it is drawn off

and fresh water added. The solution of the acid (which, as may be seen, must contain some nitric acid) is now concentrated by evaporation in leaden pans until its density is 1.84.

Sulphuric acid is also obtained by the action of heat on copperas; the latter is placed in earthenware retorts, and heated to  $400^{\circ}$  F.; the vapours which distil over are condensed, and thus constitute strong oil of vitriol, or, as it is called, Nordhausen acid. This body is composed of 2 equivalents of acid and 1 equivalent of water; its formula then is  $2\text{SO}_3 + \text{HO}$ . This acid is very dark; it contains no nitric acid, which exists in considerable quantities in the acid obtained by the common method. Its specific gravity is 1.95. Exposed to the air it fumes, and is hence called the fuming acid of Nordhausen. The fumes that escape are absolutely pure anhydrous sulphuric acid; their formula is  $\text{SO}_3$ , and they condense in beautiful white silky crystals, like snow. When placed in water they hiss like red hot iron, owing to the avidity of the union between the acid and water. When the fumes escape, sulphuric acid, plus one equivalent of water, is left in the retort or vessel from which the fumes escaped. Absolutely pure sulphuric acid does not exert any acid reactions; these are only developed by water, which really acts the part of a base.

The acid of commerce is a dense, oily, colourless fluid, which boils at  $620^{\circ}$ , and has a specific gravity of 1.85. It is one of the strongest acids known, and when undiluted, powerfully corrosive. It reddens litmus, and unites with bases, forming salts called sulphates. It separates nearly all other acids from their combinations. It freezes at  $-15^{\circ}$ .

Sulphuric acid unites with water in very many proportions, and always gives rise to heat during the combination.

TABLE OF HYDRATES OF SULPHURIC ACID.

Nordhausen, . . .	$2\text{SO}_3 + \text{HO}$	Specific gravity	1.95
Purest Oil of Vitriol, .	$\text{SO}_3 + \text{HO}$	“ “	1.85
	$\text{SO}_3 + 3\text{HO}$	“ “	1.76
	$\text{SO}_3 + 4\text{HO}$	“ “	1.68
	&c., &c.		

*Test.*—The free acid or its soluble combinations are detected by a salt of baryta. The sulphate of baryta is always precipitated. It is known by its great insolubility, requiring 40,000 times its weight of water for solution.

*Hyposulphurous Acid.*—Formula,  $\text{S}_2\text{O}_3$ , or  $\text{SO}_2 + \text{S}$ . Equivalent, 48.

This acid is formed by digesting sulphur in a solution of any sulphite. An additional equivalent of sulphur combines with the acid giving by symbols  $\text{SO}_2 + \text{S}$ . This acid unites with bases, forming salts called hyposulphites. The hyposulphite of soda in solution is a solvent for the haloid salts of silver; it is therefore used in daguerreotyping to dissolve off the iodide of silver from the plate.

*Hyposulphuric Acid.*—Formula,  $\text{S}_2\text{O}_5$ , or  $2\text{SO}_2 + \text{O}$ . Equivalent, 72.

This is prepared by passing a stream of sulphurous acid gas through water, having suspended in it finely divided peroxide of manganese. Two equivalents of the acid take one equivalent of oxygen from the peroxide of manganese; giving  $2\text{SO}_3 + \text{O}$ . The hyposulphuric acid thus formed unites with the protoxide of manganese, forming a new insoluble salt. The manganese is then removed by baryta, which in its turn is removed by sulphuric acid, and hyposulphuric acid thus set free. It has no smell, is sour, and forms salts with lime, lead, baryta, &c.

*Chlorosulphurous Acid*,  $\text{SO}_2 + \text{Cl}$ , and *Iodosulphurous Acid*,



$\text{SO}_2 + \text{I}$ . These are compounds respectively of chlorine and iodine with sulphurous acid.

Many other compounds of oxygen and sulphur have been discovered and investigated, but as yet they have no interest for the student.

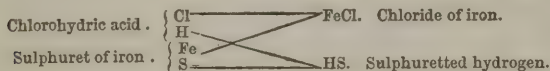
#### COMPOUNDS OF SULPHUR WITH HYDROGEN.

	Hydrogen.	Sulphur.	Equiv.	Formulae.
Sulphuretted Hydrogen, . . .	1	+	16 = 17	HS.
Bisulphuretted Hydrogen, . . .	1	+	32 = 33	HS <sub>2</sub> .

*Sulphuretted Hydrogen*.—Formula, HS. Equivalent, 17. 100 cubic inches weigh 36.54 grains. Specific gravity, 1.18.

Sulphur will not unite directly with hydrogen, unless both are in the nascent condition as gases.

The present gas is readily obtained by the action of an acid with water on the sulphuret of iron (iron pyrites). When chlorohydric acid is used, the following is the reaction: the chlorine unites with the iron, forming the chloride of iron, and the sulphur with the hydrogen, forming sulphuretted hydrogen.



When sulphuric acid and water are used, we get a sulphate of iron and the present gas.



Sulphuretted hydrogen is a colourless gas, which reddens

litmus, and is known by its offensive taste and odour, which latter is similar to rotten eggs. It is very injurious to animal life; 11.250 of it in air being sufficient to produce the death of a large animal. It extinguishes burning bodies, but burns itself with a pale blue flame, giving rise to water and sulphurous acid. Its specific gravity is 1.171. It is liquefied by a pressure of 17 atmospheres at 50°. It detonates with oxygen when mixed in the proportion of 1 to  $1\frac{1}{2}$  of the latter; the result is water and its own volume of sulphurous acid gas.

Sulphuretted hydrogen is the very best reagent the chemist possesses; because every one of the metals proper is precipitated by it per se, or when in combination with an alkali; hence a solution of sulphuretted hydrogen or a sulphuret of ammonium or potassium in water is indispensable to every laboratory.

Nearly all of its precipitates with the metals are characterized by colour.

On account of the very disagreeable odour of sulphuretted hydrogen, it becomes necessary sometimes to destroy it; this is done by chlorine; chlorohydric acid is formed, and sulphur is precipitated. It is decomposed also by the other halogen bodies, viz., bromine, iodine, &c.

*Bisulphuretted Hydrogen.*—Formula,  $\text{HS}_2$ . Equivalent, 33. Specific gravity, 1.769.

This is made by adding sulphuric acid in excess to the persulphuret of potassium. Sulphate of potassa and bisulphuret of hydrogen are obtained. It is a viscid oily liquid of a yellow colour; specific gravity, 1.769; same odour and taste as sulphuretted hydrogen.

*Bisulphuret of Carbon, or Sulphocarbonic Acid.*—Formula,  $\text{S}_2\text{C}$ . Equivalent, 38.

This has been called the alcohol of sulphur. It is got by passing the vapour of sulphur over ignited carbon in an iron tube, and then condensing it in water. It is gaseous, con-

densable at  $32^{\circ}$  F., analogous to carbonic acid, and enters into combination with sulphur bases, forming sulphocarburets.

*Bisulphuret of Cyanogen, or Sulphocyanic Acid.*—Formula,  $S_2Cy$ ; equivalent, 58.

By exposing a cyanide of iron to heat with twice its weight of sulphur, and then adding potassium, a crystalline body is obtained, which is soluble in water and alcohol. This body is the sulphocyanide of potassium. If a salt of lead is now added as the acetate, a sulphocyanide of lead is obtained. The lead may be removed by sulphuric acid, and sulphocyanogen will remain. It forms a test for iron, and Prussic acid. It will be treated hereafter.

#### IX. SELENIUM.

Symbol,	.	.	.	.	.	.	Se
Equivalent,	.	.	.	.	.	.	39.57
Specific gravity,	.	.	.	.	.	.	4.3

Selenium is found associated with sulphur. It is an amphoteric body resembling sulphur in all its habitudes.

It is a brittle solid, without taste or odour at common temperatures. In mass, it has a metallic lustre, and the aspect of lead, but in powder it is dark brown. Its specific gravity is 4.3.

It softens at  $212^{\circ}$ , and boils at  $650^{\circ}$ , giving a vapour of a deep yellow colour. It is insoluble in water. It burns with a blue flame, exhaling the odour of decaying horseradish or cabbage. Its combustion gives rise to oxide of selenium and selenious acid.

#### COMPOUNDS OF SELENIUM WITH OXYGEN.

		Selenium.	Oxyg.	Equiv.	Formulæ.
Oxide of Selenium,	.	39.57	+	8	= 47.57 $SeO$
Selenious Acid,	.	39.57	+	16	= 55.57 $SeO_2$
Selenic Acid,	.	39.57	+	24	= 63.57 $SeO_3$

*Oxide of Selenium*.—Formula,  $\text{SeO}$ ; equivalent, 47·57. This is formed by heating selenium in the air, and then washing the product to get rid of selenious acid. It is a colourless, gaseous body, and is the cause of the peculiar odour of burning selenium.

*Selenious Acid*.—Formula,  $\text{SeO}_2$ ; equivalent, 55·57. This is formed by digesting selenium in nitric acid and evaporating to dryness. It is white, soluble, deliquescent, and forms salts called selenites.

*Selenic Acid*.—Formula,  $\text{SeO}_3$ ; equivalent, 63·57. This is prepared by heating selenium with nitrate of potassa: a seleniate of potassa is obtained; this is then decomposed by nitrate of lead, giving rise to nitrate of potassa and seleniate of lead; the lead is removed by sulphuric acid, and the selenic acid left pure. It is a colourless liquid, resembling sulphuric acid very much, both in its acid properties and in its salts.

## X. PHOSPHORUS.

Symbol,	.	.	.	.	.	.	.	P
Equivalent,	.	.	.	.	.	.	.	31·38
Specific gravity,	.	.	.	.	.	.	.	1·77

Phosphorus is very abundant in nature, in primitive rocks, in plants, and animals. It exists as salts, and is found as such in animal tissues, especially in the brain and nerves; it is supposed to be essential to them.

It is now generally obtained from bones, in which it exists as the phosphate of lime. The bones are first calcined, to free them from animal matter, and then reduced to powder; to this powder is added two-thirds of its weight of sulphuric acid; this removes some of the lime, forming an insoluble sulphate of lime, which is precipitated, and a soluble superphosphate of lime remains in solution. The liquid is then removed

and evaporated to a sirupy consistence, and then heated intensely with carbon. The carbon removes the oxygen and the lime, forming a carbonate of lime, and the phosphorus is distilled over; this is then melted under water, squeezed under chamois leather, and cast into moulds.

Phosphorus, when pure, is a colourless, transparent, solid body, resembling wax very much. It fuses at  $108^{\circ}$ , and hardens at the same temperature, unless an alkali be present, in which case it does not harden until it reaches very nearly  $32^{\circ}$  Fahrenheit. Its specific gravity is 1.77. Phosphorus must be melted under water to prevent it from taking fire. Heated out of the air it becomes orange-coloured, and combustible at its original temperature, requiring a red heat to fire it; this is its allotropic state. Phosphorus is soluble in the essential oils, fats, ether, naphtha, sulphocarbonic acid, &c. Evaporated from these, it is obtained in crystals, which are octohedrons, but which become cubes when heated.

Phosphorus is very inflammable, uniting with oxygen at all temperatures. A stick of it exposed, undergoes slow combustion, emitting white vapours, which have an alliaceous odour, and are luminous in the dark. This oxidation will not go on in pure oxygen, unless its temperature be over  $70^{\circ}$ ; the product of the oxidation is phosphorous acid.

When phosphorus is fired in the open air, it forms a dense white cloud, which is solid phosphoric acid.

#### COMPOUNDS OF PHOSPHORUS WITH OXYGEN.

			Phosphorus.	Oxyg.	Equiv.	Formulae.
Hypophosphorous Acid,	.	.	31.38	+	8	= 39.38 PO
Phosphorous Acid,	.	.	31.38	+	24	= 55.38 PO <sub>2</sub>
Phosphoric Acid,	.	.	31.38	+	40	= 71.38 PO <sub>3</sub>

*Hypophosphorous Acid.*—Formula, PO; equivalent, 39.38. This cannot be made directly, but it is formed when phosphorus, water, and an alkali, are heated together. The oxygen

of the water goes to the phosphorus, forming hypophosphorous acid, which then unites with the alkali, while the hydrogen of the water goes to some ununited phosphorus, forming phosphuretted hydrogen.

*Phosphorous Acid*.—Formula,  $\text{PO}_3$ ; equivalent, 55.38. This is formed by the slow combustion of phosphorus in the air. The process should be conducted over water, by which it is dissolved out as fast as formed. Its salts are phosphites; they are of little importance.

*Phosphoric Acid*.—Formula,  $\text{PO}_5$ ; equivalent, 71.38. This acid is always formed when phosphorus is burned in the air; thus prepared it is a snow-like anhydrous body; but in this state it has no acid reactions. It unites with water with great avidity, giving rise to a hissing noise and heat. When once a hydrate, the water cannot be separated. There are several varieties of this compound, all of which, however, are isomeric bodies.

#### TABLE OF ACIDS.

Phosphoric Acid (dry),	$\text{PO}_5$	
Phosphoric Acid (common),	$\text{PO}_5 + 3\text{HO}$	Tribasic.
Pyrophosphoric Acid,	$\text{PO}_5 + 2\text{HO}$	Bibasic.
Metaphosphoric Acid,	$\text{PO}_5 + \text{HO}$	Monobasic.

*Phosphoric Acid (common)*.—Formula,  $\text{PO}_5 + 3\text{HO}$ .

This, the tribasic acid, is always got when water is added to the dry acid. The solution in water contains the tribasic phosphate of water, and by heating this solution, all the water is driven off, except the three equivalents, which may be substituted by soda or any other base. It is called tribasic, because it may have three bases united to but one equivalent of acid, and in this respect it forms the type of a class of acids, of which the organic acids form the largest number. This acid, as may be inferred, will form neutral, sub, and super salts.



The following are examples.

Neuter phosphate of soda,	. . .	$3\text{NaO} + \text{PO}_5 + 24\text{HO}.$
Sub           “           “	. . .	$\text{HO}, 2\text{NaO} + \text{PO}_5 + 24\text{HO}.$
Super       “           “	. . .	$2\text{HO}, \text{NaO} + \text{PO}_5 + 24\text{HO}.$

Of the above, the sub-salt is the common phosphate of soda of the shops.

This acid forms another remarkable salt, containing three different bases; it is called microcosmic salt. It is the phosphate of soda, ammonia, and water. Formula,  $\text{HO}, \text{NH}_4\text{O}, \text{NaO} + \text{PO}_5.$

*Pyrophosphoric Acid.*—Formula,  $\text{PO}_5 + 2\text{HO}.$

This acid, as will be seen by referring to the table, is only bibasic. It is prepared by heating a tribasic salt. For this purpose the sub-salt is used, in which the acid is in combination with 2 equivalents of soda and 1 equivalent of water. It is heated to  $415^\circ$ ; at this temperature the one equivalent of water is driven off, and the phosphoric acid is left in combination with 2 equivalents of soda. The soda may be substituted by water. This acid resembles in its general characters, phosphoric acid. It is remarkable for uniting with 2 equivalents of base. Its salts are called pyrophosphates.

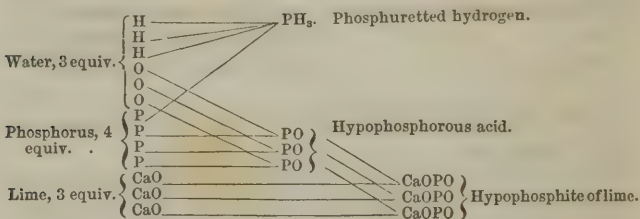
*Metaphosphoric Acid.*—Formula,  $\text{PO}_5 + \text{HO}.$

This acid is monobasic. It is obtained by heating the superphosphate of soda to a red heat. In this case the acid of the superphosphate is in combination with two equivalents of water, and one of soda; by a red heat the former are driven off, and the latter remains. The soda may be substituted by water.

#### COMPOUNDS OF PHOSPHORUS AND HYDROGEN.

*Phosphuretted Hydrogen.*—Formula,  $\text{PH}_3.$  Equivalent, 34.38. Specific gravity, 1.24.

This gas may be made by heating water, an alkali, and phosphorus together.



It will be seen by the above diagram, that the water is decomposed, its hydrogen going to part of the phosphorus, forming phosphuretted hydrogen, and its oxygen going to the rest of the phosphorus, forming hypophosphorous acid, which then unites with the lime. The gas is collected over water. This gas has long been known as the *Will of the wisp*. It is spontaneously combustible, taking fire whenever it meets oxygen. It is composed of 3 equivalents of hydrogen, and 1 equivalent of phosphorus, very much resembling ammonia. It is transparent, colourless, having an offensive odour and a bitter taste; it is a non-supporter of combustion, but is itself inflammable. When the bubbles of gas escape from the surface of the water, they take fire spontaneously, forming beautiful white rings, which rise in the air: the ring is watery vapour and phosphoric acid. If the gas be kept for some time over water, it loses its property of self-inflammability, yet it will burn by heat: the gas has suffered no appreciable change.

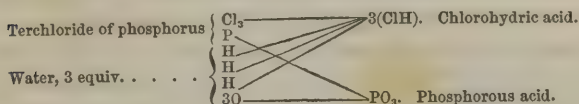
It is said to form salts with acids, like ammonia.

#### COMPOUNDS OF PHOSPHORUS WITH CHLORINE, IODINE, ETC.

Phosphorus combines with chlorine, iodine, bromine, &c., in two proportions, forming compounds containing 3 and 5 equivalents of the halogen body.

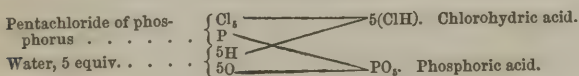
*Terchloride of Phosphorus.*—Formula,  $\text{PCl}_3$ .

The terchloride is formed when phosphorus is burned (which it does spontaneously) in a small portion of chlorine. With water it produces phosphorous acid and chlorohydric acid.



*Pentachloride of Phosphorus.*—Formula,  $\text{PCl}_5$ .

This is formed when phosphorus is burned in excess of chlorine gas; added to water, it gives chlorohydric and phosphoric acids.



What is stated above concerning chlorine and phosphorus, is true of iodine, bromine, and phosphorus.

## XI. BORON.

Symbol,	.	.	.	.	.	.	.	B
Equivalent,	.	.	.	.	.	.	.	10.90
Specific gravity,	.	.	.	.	.	.	.	.751
Volume,	.	.	.	.	.	.	.	100.

Boron was discovered in 1807 by Davy, by exposing boracic acid to the action of a powerful galvanic battery. It is obtained originally as the borax of commerce (which is a biborate of soda), from the neighbourhood of extinct volcanoes, and in the waters of the lagoons of Tuscany.

These waters are evaporated, and the biborate of soda is

left, the soda is removed by sulphuric acid, and the boracic acid is freed in tabular crystals. These are slightly acid to the taste, have a very feeble reaction, are very slightly soluble in water, and more soluble in alcohol.

By submitting the acid to a galvanic battery, or by heating it in a tube with pure potassium, boron is obtained.

Boron is a simple non-metallic element, of a dark olive colour, with neither taste nor smell, and a non-conductor of electricity. It burns at  $600^{\circ}$  with a green flame, which is characteristic. The result of the combustion is boracic acid. Its formula is  $\text{BO}_3$ . Equivalent, 34.90. Boron is analogous to carbon.

## XII. SILICON.

Symbol,	.	.	.	.	.	.	.	Si
Equivalent,	.	.	.	.	.	.	.	28.18

Silicon is the basis of silicic acid, which performs a very important part in the framework of the earth. It is a constituent of most rocks, and enters into the composition of some precious stones, as agate, topaz, &c.

Silicon is prepared by heating the double fluoride of silicon and potassium, with metallic potassium, in a glass tube; the potassium takes the place of the silicon, which is thus set free, and a double fluoride of potassium remains, which may be dissolved out, leaving the silicon.

Thus obtained, silicon has a dark nut-brown colour, without a trace of metallic lustre. Heated in the air it burns and becomes coated with silicic acid, which protects the rest.

When silicon is heated in a close crucible it becomes darker and incombustible, refusing to burn even in an oxygen-hydrogen blowpipe.

## COMPOUNDS OF SILICON WITH OXYGEN.

*Silicic Acid*.—Formula,  $\text{SiO}_3$ . Equivalent, 52·18.

This acid exists nearly pure in quartz and rock crystal; it exists also in agate, calcedony, and flint.

It is found very abundantly as the silicate of alumina and potassa, a salt very analogous to alum. The acid is got pure from these salts, by fusing them with the carbonate of soda; a silicate of soda is obtained, and the soda is removed by sulphuric acid. When separated, the acid assumes a gelatinous condition, and it is now soluble in other acids, but this property is destroyed by heat.

When dry, pure silicic acid is a light white powder, inodorous, insipid, and insoluble except recent. When fused with soda in excess, a soluble salt is obtained, formerly called *liquor silicum*. But if the acid be in excess over the alkali, another body is obtained, which is insoluble, it is *glass*.

Silicic acid is also obtained by reacting on fluoride of silicon, with water.

## XIII. FLUORINE.

Symbol,	.	.	.	.	.	.	.	Fl
Equivalent,	.	.	.	.	.	.	.	18·26.

Fluorine is one of the halogen bodies.

It has never been isolated, therefore its properties are entirely unknown.\*

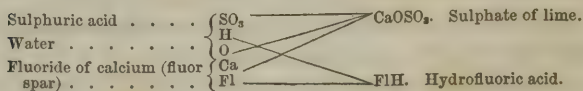
It exists in fluor or Derbyshire spar, which is a fluoride of calcium.

*Hydrofluoric Acid*.—Formula,  $\text{FlH}$ ; equivalent, 19·26.

This acid is prepared by acting on pure fluor spar, with

\* It is said that fluorine may be isolated by acting on fluor spar with sulphuric acid, in the presence of bioxide of manganese.

twice its weight of strong sulphuric acid, in a leaden or platinum retort, and applying heat.



Sulphate of lime remains in the retort, while a highly corrosive vapour distils over, which must be received in leaden or platinum receivers, surrounded by ice. It condenses into a colourless mobile liquid at  $32^\circ$ , and may be kept at  $59^\circ$  in well-stopped bottles, but exposed at this temperature, it flies off in dense white fumes. Its affinity for water is very great, so much so that on uniting with it, a hissing noise results, as when red hot iron is plunged in water.

When a drop of the strong acid is placed on the skin, a deep malignant ulcer is formed.

It will corrode glass, forming a fluoride of silicon and water, while the alkali of the glass is washed away. Glass may be etched by it, by spreading wax on it, and marking out the figures to be made, and then exposing the glass thus coated, to the vapours of the acid.

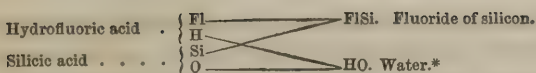
*Fluoride of Silicon.*—Formula,  $\text{FlSi}$ ; equivalent, 46.44.

This body is sometimes called fluosilicic acid.

It is formed by acting on equal parts of fluoride of calcium (fluor spar) and silicic acid or glass, with oil of vitriol. Hydrofluoric acid is first formed, and sulphate of lime precipitated (as may be seen in the reaction on the previous page).

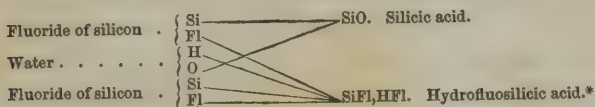
But the hydrofluoric acid being in contact with powdered glass or silicic acid, decomposes it, producing fluoride of silicon and water.





It is a colourless gas, which is incombustible, and a non-supporter of combustion or respiration.

It is decomposed by water, resulting in the production of silicic acid and a double fluoride of silicon, and hydrogen or hydrofluosilicic acid.



## SECTION V.

### METALS.

#### PHYSICAL CONSTITUTION.

THE metals are distinguished by their great opacity, even in very thin laminæ, and by their capability of receiving a polish, therefore reflecting light very much, and giving rise to the term, metallic lustre.

The metals present a very great uniformity in colour, most of them being white or whitish; the exceptions are copper and titanium, which are red, and gold, which is yellow.

The specific gravity of the metals, as a general rule, is very great, much greater than that of earth or rocks at the surface

\* The above reactions are given, to convey some idea of the actions of these bodies on each other, but literally they are not true, because silicic acid contains really 3 equivalents of oxygen, which the reactions above do not give to it.

of the globe. It is inferred, too, that the globe contains an immense amount of metallic matter, because its specific gravity is 5·6 by calculation, whereas the average specific gravity of the minerals at its surface is only 3·5. The specific gravities of the metals vary, however, very much; thus potassium and sodium are lighter than water, while platinum is nearly twenty-one times heavier than that liquid.

TABLE OF SPECIFIC GRAVITIES OF METALS AT 60° F., WATER  
BEING UNITY.

Platinum, - - - - -	21·50
Gold, - - - - -	19·50
Iridium, - - - - -	18·68
Tungsten, - - - - -	17·60
Mercury, - - - - -	13·57
Palladium, - - - - -	11·80 to 11·80
Lead, - - - - -	11·45
Silver, - - - - -	10·50
Bismuth, - - - - -	9·90
Uranium, - - - - -	9·00
Copper, - - - - -	8·96
Molybdenum, - - - - -	8·60
Cadmium, - - - - -	8·70
Cobalt, - - - - -	8·54
Nickel, - - - - -	8·80
Iron, - - - - -	7·79
Tin, - - - - -	7·29
Zinc, - - - - -	6·86 to 7·10
Manganese, - - - - -	8·
Antimony, - - - - -	6·80
Tellurium, - - - - -	6·11
Arsenic, - - - - -	5·88
Titanium, - - - - -	5·30
Chromium, - - - - -	5·90
Sodium, - - - - -	0·972
Potassium, - - - - -	0·865

Some metals possess the property of *malleability*, that is, they can be beaten into thin plates or leaves, by rolling or hammering. The malleable metals are gold, silver, copper, tin, platinum, palladium, cadmium, lead, zinc, iron, nickel, potassium, sodium, and frozen mercury. Gold is the most malleable: it may be beaten into leaves requiring 282,020 to make an inch in thickness.

Nearly all malleable metals are *ductile*, that is, they may be drawn out in wires; but ductility and malleability are not in proportion to each other: the former depends on a property called *tenacity*, which is measured by ascertaining the greatest weight a wire of given thickness can support without breaking. According to experiment, iron is the most tenacious, and copper next, while lead is the least tenacious of the metals.

Metals differ among themselves in *hardness*; among the hard metals are titanium, manganese, iron, nickel, copper, zinc, and palladium.

The power of *crystallizing* belongs to some of the metals. Thus zinc, bismuth, and antimony, are lamellated, and gold, silver, and copper, often occur naturally in crystals.

All metals are solid at common temperatures except mercury; but their points of fusion vary very much.

TABLE OF FUSIBILITY OF METALS.

					Fahrenheit.
Fusible below red heat.	{	Mercury,	-	-	-39
		Potassium,	-	-	+136°
		Sodium,	-	-	190°
		Cadmium,	-	-	442°
		Tin,	-	-	442°
		Bismuth,	-	-	497°
		Lead,	-	-	612°
		Arsenic sublimes without fusing.			
		Zinc,	-	-	773°
		Antimony—just below red heat.			

	Silver, - - - - -	1873°
	Copper, . - - - -	1996°
	Gold, - - - - -	2016°
	Iron—Cast - - - - -	2786°
	Iron—Pure, {	
	Manganese, {	
	Cobalt, {	
	Nickel, {	
	Palladium, {	Fusible at highest heat of smith's forge.
Infusible below red heat.	Molybdenum, {	
	Uranium, {	
	Tungsten, {	
	Chromium, {	Slightly fusible in smith's forge, but readily fusible before oxy- hydrogen blowpipe.
	Titanium, {	
	Cerium, {	
	Osmium, {	
	Iridium, {	
	Rhodium, {	
	Platinum, {	Infusible in forge, but fused by oxy-hydrogen blowpipe.
	Columbium, }	

Some metals possess the very valuable quality of *welding*; that is, they will unite one piece with another at certain temperatures, and form one solid compact piece. Iron, sodium, and platinum, belong to this class.

#### CHEMICAL RELATIONS.

The chemical relations of the metals are as various as the elementary bodies themselves, and they may be said to unite either directly or indirectly with all. The compounds they form with each other are called alloys, and where mercury is one of the ingredients, the compound is called an amalgam. With the simple non-metallic bodies the metals form oxides, chlorides, sulphurets, carburets, &c.

1. *Oxides*.—When the combination of a metal with oxygen

has neither acid nor alkaline properties, it is termed a base or an oxide; the most basic of all the oxides is the protoxide. When it possesses an acid reaction, that is, reddens litmus paper, it is termed an acid. When it changes vegetable blues to green, it has an alkaline reaction, and is termed an alkali. The bases or oxides and the alkalies form with acids compounds called salts. The acids of the metals form salts with other bases.

Salts are divided into two great classes, viz., amphigen and halogen salts.

The amphigen salts are those formed of bodies which generate both acids and bases, as those resulting from compounds of oxygen, sulphur, selenium, &c.

The halogen salts are those resembling sea salt (chloride of sodium).

The *amphigen salts* are divided into

1. *Sub or Basic Salts*.—These are those which have the base in excess over the acid. Under this head must not be included all polybasic salts; because some acids will unite with more than one equivalent of base, and yet form neutral salts. The distinctions among these may be seen by referring to Phosphoric Acid.

2. *Neutral Salts*.—These have generally one equivalent of base and one equivalent of acid; they are called so whether they be acid or alkaline. The general rule, however, in the formation of a neutral amphigen salt, is as follows: *that there are as many equivalents of acid as there are equivalents of oxygen in the base to which it is attached*.

Thus, one equivalent of acid is sufficient to neutralize a protoxide; but it takes two equivalents of acid to form a neutral salt with one equivalent of a deutoxide; or three equivalents to neutralize a sesquioxide. Thus the sulphate of the sesquioxide of iron is written as follows:  $(\text{Fe}_2\text{O}_3\text{SO}_3)$ .

3. *Super or Acid Salts*.—These are those in which the

acid is in excess. That is, there may be two equivalents of acid to one of base, as in the bicarbonate of soda; formula,  $\text{NaO}, 2\text{CO}_2$ .

All that has been said concerning oxides and oxy-salts is also true of the sulphurets, seleniurets, and telluriets.

*Halogen Salts.*—The halogen salts differ entirely from the amphigen. The former are bi-elementary, while the latter are composed of two bi-elementary bodies. The type of these salts is the chloride of sodium. All the halogen salts are included under the compounds of chlorine, iodine, bromine, fluorine, and cyanogen.

*Double Salts.*—Besides the two great classes of salts mentioned, it has been attempted to form a third, viz., *double salts*, but these more properly come under the former classes, as the case may be.

These double salts may then be either amphigen or halogen; thus, the chloride of sodium will unite with the chloride of mercury, and form a double haloid salt; while alum, which is the sulphate of alumina united to the sulphate of potassa, is a double amphigen salt.

All salts, of whatever class, are characterized by their taste, and by assuming certain crystalline forms.

#### CRYSTALLIZATION.

By crystallization, is meant the assumption of certain geometrical figures by bodies, in which figures certain parts are symmetrical.

Bodies assume these forms by their molecular forces or attractions.

Those forms made in nature are the most perfect, because there is sufficient time allowed for the forces to act.

Crystals have a tendency to split in particular directions,



this is called their cleavage; it is an indication of regular structure within.

Every substance has its own crystalline form; but some forms are common to a great many bodies. The same substance, too, may have two crystalline forms at different temperatures, as sulphur and carbon; such bodies are said to be *diamorphous*.

The angles of crystals are measured by an instrument called a *goniometer*.

All crystalline forms may be arranged under six classes:—

1. *The Regular System, or the Monometric System*.—The term monometric means one *measure* for all axes. The simplest form of this class, is a cube; it has 3 axes, two horizontal, and 1 vertical; the axes are all perpendicular to each other. An octohedron has precisely the same arrangement, only that the solid angles are truncated. Iron pyrites is of this form. It is evident that if we still truncate the angles equally, we still preserve the axes the same; so that we can get bodies of any number of sides.

The most important forms are the *cube*, the *regular octohedron*, and the *rhombic dodecahedron*.

2. *The Dimetric, or Square Prismatic System*.—In this there are two equal and one unequal axis. There are two varieties of it, viz., those in which the end may be a square, and those in which it is a rectangle; their angles may be also truncated to any extent. The yellow prussiate of potash is of this form.

3. *The Trimetric, or Right Prismatic System*.—This is characterized by axes, three in number, and all unequal. The end is necessarily a rectangle, unless truncated. Sulphate of potash, nitrate of potash, sulphate of baryta, &c., are of this variety.

4. *The Oblique Prismatic System*.—This has 3 axes

which are all inclined; two of them are equal, and the other unequal. Carbonate of soda is of this variety.

6. *The Doubly Oblique Prismatic System*.—This variety has 3 unequal axes and all of them inclined. Sulphate of copper is of this form.

6. *The Rhombahedral System*.—This system has 4 axes; 3 of them are equal, and at an angle of  $60^\circ$  to each other, and all in the same horizontal plane, while the fourth axis is perpendicular and unequal. Quartz is of this form.

#### ISOMORPHISM.

The term isomorphism is applied to those elements and compounds which have the same crystalline form. Thus the sulphate of alumina will unite with the sulphate of potassa and form an alum having crystals of an octohedral form; and ammonia and soda will also form alums with the sulphate of alumina, having the same octohedral crystals. Ammonia, soda, and potassa, are hence said to be isomorphous.

Isomorphous substances frequently have very remarkable points of resemblance beside form. Thus, phosphorus and arsenic have the same alliaceous odour, and form the same compounds with hydrogen.

In the formation of double salts, the two bases are never taken from the same isomorphous family. Sulphate of potassa may be made to unite with the sulphate of alumina and form a double salt, but it will never unite with the sulphate of soda, which belongs to the same family.

The chemical constitution of substances has been inferred from their isomorphism. Thus, alumina is called the sesquioxide of aluminum, on account of its intimate relation to the sesquioxide of iron, the constitution of which is known, while that of alumina would otherwise be unknown.

## ISOMORPHOUS GROUPS.

1.	5.
Chlorine,	Magnesium,
Bromine,	Manganese,
Iodine,	Iron,
Fluorine.	Cobalt,
	Nickel,
2.	Zinc,
Sulphur,	Copper,
Selenium,	Cadmium.
Tellurium.	
	6.
3.	Phosphorus,
Barium,	Antimony,
Strontium,	Arsenic.
Lead.	
	7.
4.	Aluminum,
Potassium,	Chromium,
Sodium,	
Ammonium,	
Silver.	

## THE BINARY CONSTITUTION OF SALTS.

The binary theory classes all salts as binary compounds analogous to the chloride of sodium. This is as true probably as the old theory, which supposes the amphigen salts to be composed of two binary compounds, because, it is as absolutely impossible to prove the one as the other, in the present state of chemical knowledge. The binary theory has, however, this advantage over the other, viz., of being a greater generalization.

The sulphate of soda is supposed by the old views to be a

sulphate of the oxide of sodium; formula  $\text{NaO}, \text{SO}_3$ : but the binary theory supposes that the oxygen of the soda may go to the sulphuric acid, giving  $\text{SO}_4$ , and this, then, may unite with sodium; the formula being  $\text{NaSO}_4$ . The  $\text{SO}_4$  is here supposed to act as a compound radical, precisely like cyanogen, which is a compound body, and yet comports itself like an element; and the salt represented by the formula  $\text{NaSO}_4$ , is on such a supposition called the sulphionide of sodium, instead of the sulphate of soda.

The above view is ingenious and extremely probable when it is remembered that in the sulphate of water ( $\text{SO}_3 \text{HO}$ ) the hydrogen may be replaced by zinc, or iron, or manganese, &c., while the oxygen always remains, no matter what the disturbing causes may be; hence it would seem proper at least to write its formula as  $\text{SO}_4\text{H}$  instead of  $\text{SO}_3\text{HO}$ .

Again, absolute acids are known to exert no acid properties whatever, unless water is present, which gives an additional equivalent of oxygen, and then the acid is capable of forming salts, and not until then.

## CLASSIFICATION OF METALS.

The metals are divided into six great classes: these are—

### I. THE METALS OF THE ALKALIES.

Potassium,	Lithium,
Sodium,	Ammonium.

### II. METALS OF THE ALKALINE EARTHS.

Barium,	Calcium,
Strontium,	Magnesium.

III. METALS OF THE EARTHS PROPER.

Aluminum,	Yttrium,
Glucinum,	Zirconium,
Thorium.	

IV. METALS PROPER, WHOSE OXIDES ARE BASES.

Manganese,	Lanthanum,
Iron,	Cadmium,
Zinc,	Nickel,
Cobalt,	Bismuth,
Copper,	Cerium,
Lead,	Uranium.

V. METALS PROPER, WHOSE OXIDES ARE ACIDS OR WEAK BASES.

Chromium,	Titanium,
Vanadium,	Tin,
Tungsten,	Antimony,
Molybdenum,	Arsenic,
Columbium,	Tellurium,
Osmium.	

VI. METALS WHOSE OXIDES ARE REDUCIBLE BY HEAT.

Gold,	Mercury,
Silver,	Platinum,
Palladium,	Iridium,
Rhodium.	

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CLASS I.

METALS OF THE ALKALIES.

POTASSIUM.

Symbol,	.	.	.	.	.	.	K
Equivalent,	.	.	.	.	.	.	39.19
Specific gravity,	.	.	.	.	.	.	.865
Melts at	.	.	.	.	.	.	150°

Potassium was first obtained by Davy by the action of a battery on potassa. It is also got by heating the alkali intensely with finely-divided charcoal; but the process now most usually resorted to is, to first carbonize bitartrate of potassa by heat; a mixture of carbon and potassa is obtained (tartaric acid being an organic body containing much carbon), which mixture is called *black flux*; this is now heated intensely in an iron retort; the metal is reduced and received in naphtha, a body which contains no oxygen.

Potassium is, at common temperatures, a soft metallic body, easily cut by a knife, and capable of being moulded. It is white, brilliant, and has the lustre of steel. It is brittle at  $32^{\circ}$ ; melts at  $150^{\circ}$ , and volatilizes at  $180^{\circ}$ .

Exposed to air, potassium tarnishes, by absorbing oxygen and being converted into potassa; in fact, this facility of oxidation is its most prominent property, and it is, therefore, preserved in fluids, which contain no oxygen.

Potassium is lighter than water, specific gravity,  $\cdot 865$ . When thrown on water it floats, at the same time, taking fire, and burning with a beautiful roseate flame, taking oxygen from the water and liberating hydrogen. It explodes after combustion, because, while burning, it assumes a spheroidal condition, and as soon as it cools sufficiently, steam is generated with explosive violence. For every 9 grains of water decomposed,  $39\cdot 19$  grains of potassium are consumed. The chemical name for potassium is *Kalium*, hence its symbol is K. The product of the combustion of potassium is the protoxide or potassa.

#### COMPOUNDS OF POTASSIUM WITH OXYGEN.

	Potass.	Oxyg.	Equiv.	Formulae.
Protoxide, . .	39·19	+ 8	= 47·19	KO
Teroxide, . .	39·19	+ 24	= 63·19	KO <sub>2</sub>

*Protoxide; Potassa.*—Formula, KO; equivalent, 47·19.



To obtain pure potassa (potash) without water, the metal should be treated with dry air or oxygen gas.

Anhydrous potassa is a white, solid substance, highly caustic, having a powerful affinity for water, and disengaging intense heat during the combination.

*Hydrate of Potassa*, KO, HO. The potash which we commonly see is not dry potassa; it always has one or more equivalents of water.

Potash is very abundant in nature, in many rocks, &c., as granite, which is composed of mica, quartz, and feldspar, the latter being a silicate of potash. The disintegration of such rocks as the above produces soils, which thus containing potash, yield it to the plants, and hence the ashes of these plants, contain the potash. It is obtained from these ashes by lixiviation and evaporation in iron pots, hence called pot-ashes. It is got thus as the carbonate. The pure alkali is obtained from the carbonate by boiling it in water and adding lime in excess; carbonate of lime is precipitated, and potassa remains in solution. The solution is evaporated to dryness, dissolved by alcohol to purify; and again evaporated.

The potassa thus obtained, is called caustic potassa; it is the protohydrate. It is white, solid, deliquescent, semicrystalline, very soluble in water, and soluble in alcohol. It destroys all animal textures, and on this account it is used as a caustic. It is a most powerful alkali, capable of neutralizing the strongest acids. It is used to dry gases, which it does by absorbing their water, which latter then dissolves the alkali; hence potassa is said to be *deliquescent*.

When it is wished to separate other bases from their acids, either potassa or soda, as a general rule, is used, because of their powerful alkaline properties. Hydrate of potassa absorbs carbonic acid from the air, and hence should be kept in well-stopped bottles.

*Teroxide of Potassium*.—Formula,  $\text{KO}_3$ ; equivalent, 63.19.

When potassium burns in an excess of oxygen, an orange-coloured, fusible substance is generated, which is the teroxide. It is also obtained by the decomposition of nitre by heat, in metallic vessels. When the teroxide is put in water, it is converted into potassa and oxygen gas.

## OXY-SALTS OF POTASSA.

The salts of potassa are very numerous, the principal only are presented. The whole number of inorganic salts of all kinds is immense ; 25 years ago those known exceeded 30,000.

	Potassa. Acid.	Equivalents.	
Carbonate, . .	KO, CO <sub>2</sub>	= 47·19 + 22·	= 69·19
Bicarbonate, . .	KO, CO <sub>2</sub> + HO, CO <sub>2</sub>	= 69·19 + 31·	= 100·19
Sulphate, . .	KO, SO <sub>3</sub>	= 47·19 + 40·	= 87·19
Bisulphate, . .	KO, SO <sub>3</sub> + HO, SO <sub>3</sub>	= 87·19 + 49·	= 136·19
Nitrate, . . .	KO, NO <sub>5</sub>	= 47·19 + 54·04	= 101·23
Chlorate, . .	KO, ClO <sub>5</sub>	= 47·19 + 75·41	= 122·60
Iodate, . . .	KO, IO <sub>5</sub>	= 47·19 + 166·36	= 213·55
Bromate, . .	KO, BrO <sub>5</sub>	= 47·19 + 118·26	= 165·45
Phosphates,		Polybasic.	
Borate, &c. &c.			

*Carbonate of Potassa.*—Formula, KO, CO<sub>2</sub> ; equivalent, 69·19.

The carbonate is the form in which potassa is got from land plants. These are burned, lixiviated, and evaporated, giving impure carbonate of potassa. The carbonic acid is the result of combustion, because the potassa exists in the plants as the acetate, that is, in combination with acetic acid, which is an organic acid containing carbon, and which is converted into carbonic acid by combustion; the acid thus formed unites with the alkali. It is treated with water and evaporated; the salt crystallizes from the solution.

The present salt is obtained perfectly pure, by exposing

cream of tartar to a red heat; it is hence frequently called *salt of tartar*. It unites with two equivalents of water, and crystallizes in oblique rhombic prisms. It is deliquescent, very soluble in water, insoluble in alcohol, and has an alkaline reaction, although chemically it is a neutral salt. By exposing it to heat, it is rendered anhydrous.

*Bicarbonate of Potassa*.—Formula,  $\text{KO}, \text{CO}_2 + \text{HO}, \text{CO}_2$ ; equivalent, 100·19.

This salt, formerly called the supercarbonate, is prepared by passing a stream of carbonic acid gas through a solution of carbonate of potassa. The salt crystallizes out from its solution in right rhombic prisms. It is really a double salt, being the carbonate of potassa plus the carbonate of water. When heated, the salt is decomposed into carbonate of potassa, and carbonic acid, which escapes.

*Sulphate of Potassa*. — Formula,  $\text{KO}, \text{SO}_3$ ; equivalent, 87·19.

This may be obtained by the direct union of the two bodies forming it. It is also got, by adding carbonate of potassa to the bisulphate, which is a residuum, after obtaining nitric acid, by the action of sulphuric acid on nitrate of potassa. It is an anhydrous salt, crystallizing in six-sided prisms, crepitating in the fire, soluble in water, but insoluble in alcohol. It is distinguished from sulphate of soda, by not being efflorescent, and requiring 15 times as much water to dissolve it.

*Bisulphate of Potassa*. — Formula,  $\text{KO}, \text{SO}_3 + \text{HO}, \text{SO}_3$ ; equivalent, 136·19.

This is prepared by adding half its weight of oil of vitriol to the neutral sulphate. It is a double salt, having a sour taste and an acid reaction. It is much more soluble than the neutral salt.

*Nitrate of Potassa; Nitre; Saltpetre*.—Formula,  $\text{KO}, \text{NO}_3$ ; equivalent, 101·23.

Nitrate of potassa is obtained in nature by the decomposition of organic matter containing nitrogen, in the presence of an alkali, generally lime. The organic matter furnishes nitrogen to the oxygen of the air, which thus forms nitric acid, and this unites to the lime, forming nitrate of lime. The earth containing this is thrown in water, and the salt dissolved out; then the ashes of land-plants (which contain carbonate of potassa) are added, and the potassa takes the place of the lime, while carbonate of lime is precipitated. The nitrate of potassa remains in solution; this solution is evaporated, and the salt crystallizes out, in six-sided prisms. They absorb water, and have a cool saline taste. The natural process for obtaining nitrate of potassa, is now artificially imitated in France and Germany.

When this salt is heated, it is decomposed, giving off much oxygen, leaving a hyponitrate of potassa. It is not combustible, but it is a supporter of combustion, and hence the reason why when heated, and brought in contact with combustible bodies, rapid combustion takes place, amounting sometimes to an explosion. It is the constituent in gunpowder, which imparts the oxygen to sulphur and carbon. This body is made by intimately mixing 1 equivalent of nitre, 3 equivalents of carbon, and 1 equivalent of sulphur. These in the 100 parts are very nearly in the following proportions; viz. :

Nitrate of potassa,	.	.	.	.	.	75
Carbon,	.	.	.	.	.	15
Sulphur,	.	.	.	.	.	10
						<hr/> 100

When gunpowder is burned, six equivalents of oxygen are given off, which go to the sulphur and carbon, forming carbonic oxide and sulphurous acid gas, and nitrogen is set free; at the same time a sulphocyanide of potassium is sometimes formed, and always the sulphuret. At  $60^{\circ}$  these gases occupy

200 times the volume of the powder, but the explosion takes place at a red heat,  $1000^{\circ}$  F.; hence the enlargement of volume must be immense.

*Chlorate of Potassa.* — Formula,  $\text{KO}, \text{ClO}_3$ ; equivalent, 122.60.

Chlorate of potassa is made by passing chlorine gas through a saturated solution of potassa; chloride of potassium and chlorate of potassa are both formed. The solution is gently cooled and evaporated, and the chlorate crystallizes out from the solution, in flattened tabular crystals.

Chlorate of potassa is readily decomposed, giving off 6 equivalents of oxygen, and leaving chloride of potassium; hence it is very powerfully deflagrating. Triturated with sulphur or phosphorus, little explosions take place. It has been proposed as a substitute for nitre, in gunpowder, but such is the violence of its explosion, as to shatter the strongest cannon.

*Silicate of Potassa.* — Formula,  $\text{KO}, \text{SO}_3$ ; equivalent, 99.37.

Silicic acid unites in different proportions with the alkalies. If the alkali be in excess, the salt formed will be soluble in water; the solution is called the liquor of flints, or soluble glass. But if the silicic acid be in excess, the salt formed is perfectly insoluble in water,—it is *glass*.

Glass is fusible at a temperature a little below whiteness, and it is capable of being moulded. It is not crystalline, but it always breaks with a conchoidal fracture.

Pure colourless glass is essentially a silicate of potassa and lime. The purest is made in Bohemia.

Glass is coloured by the metallic oxides: the purple of Cassius makes it purple; the oxide of manganese, amethyst; the red oxide of copper, ruby; oxide of iron, green; oxide of cobalt, blue; oxide of silver, lemon colour, &c. Glass is made opaque and white by the oxide of tin; this is enamel.

## HALOID SALTS OF POTASSIUM.

Chloride, . . . .	KCl . .	39·19 + 35·41 = 74·60
Iodide, . . . .	KI . .	39·19 + 126·36 = 165·55
Bromide, . . . .	KBr . .	39·19 + 78·26 = 117·45

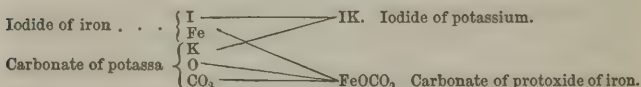
*Chloride of Potassium.*—Formula, KCl; equivalent, 74·60.

The chloride is obtained in making chlorate of potassa, by passing chlorine gas through a solution of potassa; it remains in the mother waters after obtaining the chlorate, and it is got from these waters by crystallization. It resembles common salt very much, and has a simple saline taste.

*Iodide of Potassium.*—Formula, KI; equivalent, 165·55.

This is prepared by adding iodine to a strong solution of caustic potassa; the iodine is dissolved, and the solution contains iodide of potassium and iodate of potassa, precisely as in the case of chlorine passed into the same solution.

It is also made by adding iodide of iron to the carbonate of potassa in solution.



The carbonate of iron is precipitated, and the iodide of potassium is allowed to crystallize from the supernatant liquid. It occurs in anhydrous cubes, which fuse by heat. The salt is soluble in water and alcohol; its solution in water possesses the property of dissolving large quantities of free iodine. It is much used in medicine.

*Bromide of Potassium.*—Formula, KBr; equivalent, 117·45.

This is obtained like the others; it is colourless, soluble, &c.



## SULPHURETS OF POTASSIUM.

There are three sulphurets, viz., the proto, ter, and penta-sulphuret.

The *protosulphuret* is prepared by heating the sulphate of potassa with carbon; the oxygen is removed by the carbon, and the sulphur of the sulphuric acid is left in combination with the potassium. The other compounds are prepared by heating the protosulphuret with different proportions of sulphur. They are all brownish, solid bodies, soluble in water, to which they give an exceedingly offensive and acrid taste. They are very valuable to the chemist as reagents.

## TESTS OF POTASSIUM.

1. Potassium gives a roseate hue to flame.
2. The salts of potassa are generally colourless, and tolerably soluble in water.
3. Tartaric acid added to a solution of potassa, gives the white precipitate, cream of tartar (acid tartrate of potassa), which requires 500 times its weight of water to dissolve it.
4. The bichloride of platinum forms a yellow precipitate with potash, which is the double chloride of platinum and potassium.

## SODIUM.

Symbol,	.	.	.	.	.	.	Na
Equivalent,	.	.	.	.	.	.	23·27
Specific gravity,	.	.	.	.	.	.	0·972
Melts at	.	.	.	.	.	.	194°

Sodium is obtained by decomposing carbonate of soda by charcoal, at high temperatures.

Sodium is a silver-white metal, resembling potassium very

much; it is soft at common temperatures, melts at  $194^{\circ}$ , and oxidizes rapidly in the air. When sodium is thrown on water, it does not burn, because its affinity for oxygen is not so great as potassium, therefore there is not sufficient heat evolved to fire the sodium; but if we use a bad conductor, as charcoal, and place the sodium on it, sprinkling it at the same time with water, it will be fired, because the heat is not conducted off. Its flame is yellow, which is characteristic. The scientific name for sodium is Natrium, hence its symbol Na.

#### COMPOUNDS OF SODIUM WITH OXYGEN.

	Formula.	Sodium.	Oxygen.	Equiv.
Protoxide, . . .	NaO . .	23·27	+	8 = 31·27
Teroxide, . . .	NaO <sub>2</sub> . .	23·27	+	24 = 47·27

*Protoxide of Sodium; Soda.*—Formula, NaO; equivalent, 31·27.

Soda is prepared in precisely the same way as potassa, only marine plants are employed instead of land plants. It generally exists in the form of a hydrate (NaO, HO). The solid hydrate is white, fusible, and resembles the hydrate of potash. It is deliquescent, very soluble, and powerfully alkaline.

#### OXY-SALTS OF SODA.

	Soda.	Acid.	Equivalents.	
Carbonate, . .	NaO, CO <sub>2</sub> +10HO		31·27+112	=143·27
Bicarbonate, .	NaO, CO <sub>2</sub> +HOCO <sub>2</sub>		40·27+ 44	= 84·27
Sulphate, . .	NaO, SO <sub>3</sub> +10HO		31·27+ 40+ 90	=161·27
Bisulphate, . .	NaO, SO <sub>3</sub> +HOSO <sub>3</sub>		40·27+ 80	=120·27
Nitrate, . . .	NaO, NO <sub>3</sub>		31·27+ 54·04	= 85·31
Chlorate, . .	NaO, ClO <sub>3</sub>		31·27+ 75·41	=106·68
Phosphate, . .	Polybasic.			
Biborate, . .	NaO <sub>2</sub> BO <sub>3</sub> +10HO		31·27+69·80+90	=191·07

*Carbonate of Soda.*—Formula,  $\text{NaO}, \text{CO}_2 + 10\text{HO}$ ; equivalent, 143·27.

Carbonate of soda is obtained from the ashes of sea plants, in the manner already stated for obtaining carbonate of potassa from the ashes of land plants. It is also obtained on a large scale from common salt, which is first converted into sulphate of soda, and then into the carbonate.

The crystals of carbonate of soda generally contain 10 equivalents of water, but by management they may be made to contain only 7. This salt is efflorescent; when heated it melts in its own water of crystallization. It is soluble in 2 parts of cold water, and much less boiling water. Although a neutral salt, it has an alkaline taste and a powerful alkaline reaction.

*Bicarbonate of Soda.*—Formula,  $\text{NaO}, \text{CO}_2 + \text{HO}, \text{CO}_2$ ; equivalent, 84·27.

This salt, commonly called the super-carbonate, is prepared by passing a stream of carbonic acid gas through a saturated solution of neutral carbonate. It is a double salt, viz., the carbonate of soda and the carbonate of water. The neutral carbonate loses 9 equivalents of water during the process, and also its crystalline form, becoming a white powder. This salt is also a neutral one, containing 2 equivalents of acid, and 2 of base, yet it is also alkaline in taste and reaction.

*Sulphate of Soda.*—Formula,  $\text{NaO}, \text{SO}_3 + 10\text{HO}$ ; equivalent, 161·27.

Sulphate of soda is commonly called Glauber salt. It exists in sea water, and is a residuum from obtaining common salt by evaporation. It is also a residue from preparing hydrochloric acid by the action of sulphuric acid on the chloride of sodium dissolved in water. By adding sulphuric acid to carbonate of soda, it is obtained pure. It crystallizes in four-sided prisms, with dihedral summits, which are efflorescent,

and melt by heat in their own water of crystallization. They are soluble in twice their weight of cold water.

*Bisulphate of Soda.*—Formula  $\text{NaO}, \text{SO}_3 + \text{HO}, \text{SO}_3$ ; equivalent, 120·27.

This is prepared by the addition of sulphuric acid to the neutral sulphate.

*Nitrate of Soda.*—Formula,  $\text{NaO}, \text{NO}_5$ ; equivalent, 85·31.

Nitrate of soda is obtained naturally and artificially in the same way that nitrate of potassa is. It crystallizes as a rhomb, very much resembling a cube. It does not effloresce, because it contains no water of crystallization; but it deliquesces. Nitrate of soda is used in pyrotechny, because it burns the combustibles with which it is mixed much more slowly than the nitrate of potassa.

*Chlorate of Soda.*—Formula,  $\text{NaO}, \text{ClO}_5$ ; equivalent, 106·68. This salt resembles chlorate of potassa in every respect.

*Phosphates of Soda.*—These are polybasic salts; consisting of one equivalent of acid united to one, two, or three equivalents of the alkali.

*Tribasic Phosphates of Soda.*—Of these there are three varieties, viz.:

Neuter phosphate of Soda,	. .	$3\text{NaO}, \text{PO}_5 + 24\text{HO}.$
Sub,	“ “ “ . .	$\text{HO}, 2\text{NaO}, \text{PO}_5 + 24\text{HO}.$
Super,	“ “ “ . .	$2\text{HO}, \text{NaO}, \text{PO}_5 + 24\text{HO}.$

*The subsalt* is the common phosphate of soda of the shops. It is obtained by adding carbonate of soda to the acid phosphate of lime. It crystallizes in large rhombs; they are efflorescent, soluble in four parts of water, and have a purely saline taste.

Besides the above salts, there is a singular one called microcosmic salt; it is the tribasic phosphate of soda, ammonia, and water. Formula,  $\text{HO}, \text{NH}_4\text{O}, \text{NaO}, \text{PO}_5.$

*Bibasic Phosphate of Soda; Pyrophosphate of Soda.*—Formula,  $2\text{NaO}, \text{PO}_5 + 10\text{HO}$ .

This salt is prepared by heating; the tribasic salt containing 2 equivalents of soda and one of basic water to  $415^\circ \text{F}$ .

*Monobasic Phosphate of Soda; Metaphosphate of Soda.*—Formula,  $\text{NaO}, \text{PO}_5$ .

This is prepared by heating the acid tribasic phosphate (containing two equivalents of basic water, and one equivalent of soda), to a red heat. It is transparent, glassy, deliquescent, and very soluble in water.

*Biborate of Soda; Borax.*—Formula,  $\text{NaO}, 2\text{BO}_3 + 10\text{HO}$ ; equivalent, 191.07.

This occurs in certain lakes in Persia, and in the lagoons of Tuscany. The waters are evaporated and the salt is left. It crystallizes in six-sided prisms, which are efflorescent.

Borax is used in the arts in soldering metals.

#### HALOID SALTS OF SODIUM.

Chloride, . . . .	NaCl	23.27 + 35.41 =	58.68
Iodide, . . . .	NaI	23.27 + 126.36 =	149.63
Bromide, . . . .	NaBr	23.27 + 78.26 =	101.53
&c., &c.			

*Chloride of Sodium; Common Salt.*—Formula,  $\text{NaCl}$ ; equivalent, 58.68.

Common salt is found very abundantly in sea water. In oceans it constitutes  $2\frac{7}{10}$  per cent.; but it varies in different parts of the same ocean, and in different oceans; thus the Dead Sea holds 6 per cent. of salt. It is also found in beds of solid salt in different parts of the world, and in saline springs. The principal brine springs in the United States are at Syracuse, N. Y., Kanhawa, Va., and Kiskiminitas, Pa. From these springs it is obtained by evaporation. It crystallizes in regular cubes, soluble in hot and cold water, both dissolving the same amount, viz., 37 per cent.

*Iodide of Sodium*,  $\text{NaI}$ , and *Bromide of Sodium*,  $\text{NaBr}$ , very much resemble the corresponding compounds of potassium.

#### SULPHURETS OF SODIUM.

*Sulphuret of Sodium*.—Formula,  $\text{NaS}$ ; equivalent, 39.27.

This is prepared in the same way as the corresponding compound of potassium.

#### TESTS OF SODIUM.\*

1. Soda gives a yellowish tinge to flame.
2. The soda salts are generally soluble, and efflorescent.
3. The bichloride of platinum forms a precipitate with potassa, and not with soda.
4. The only insoluble salt of soda is the antimoniate ( $\text{NaO}$ ,  $\text{SbO}_5$ ); while the antimoniate of potash is soluble.

#### LITHIUM.

Symbol,	.	.	.	.	.	L
Equivalent,	.	.	.	.	.	6.43.

Lithium is got by electrolyzing the hydrate of lithia in contact with mercury: an amalgam of mercury and lithium is thus formed; the metal is obtained by distilling the amalgam. It is white, like sodium, and very readily oxidized.

#### COMPOUNDS OF LITHIUM AND OXYGEN.

Protoxide, . . .  $\text{LO}$  . . .  $6.43 + 8 = 14.43$ .

*Protoxide of Lithium*; *Lithia*.—Formula,  $\text{LO}$ ; equivalent, 14.43.

This oxide is found in spodumene, petalite, and most of

\* The compounds of potassium are the only ones with which those of sodium are likely to be confounded.



the micas. It is not so soluble as potassa. Its salts are of no importance. Lithia colours flame carmine red.

## AMMONIUM.

Symbol, . . . . .	NH <sub>4</sub>
Equivalent, . . . . .	18·06

Ammonium is a hypothetical radical or metal, the constitution of which has already been treated of, under the head of Nitrogen.

## OXIDES OF AMMONIUM.

Protoxide, . . NH<sub>4</sub>O . . 18·06+8=26·06.

*Protoxide of Ammonium; Ammonia.*—Formula, NH<sub>4</sub>O; equivalent, 26·06.

Ammonia is a gaseous body, readily obtained from the chloride of ammonium, by heating it in a retort with quicklime; double decomposition takes place, resulting in the formation of oxide of ammonium, and chloride of calcium.

The gas has a pungent odour, is colourless, and has a strong alkaline reaction. It is condensable into a liquid by a pressure of 6·5 atmospheres at 60° F. Water absorbs 700 times its volume of ammonia, forming a solution called *liquor ammoniæ*, the density of which is ·875.

100 cubic inches of the gas weigh 18·26 grains; specific gravity ·589.

Ammonia is a very powerful alkali. It is arranged under the same class as soda and potassa.

## OXY-SALTS OF AMMONIA.

Carbonate, . . . NH <sub>4</sub> O, CO <sub>2</sub> . .	26·06+22·	=48·06
Sulphate, . . . NH <sub>4</sub> O, SO <sub>3</sub> +HO	26·06+49·	=75·06
Nitrate, . . . NH <sub>4</sub> O, NO <sub>5</sub> . .	26·06+54·04	=80·10
&c. &c.		

*Carbonate of Ammonia*.—Formula,  $\text{NH}_4\text{O}, \text{CO}_2$ ; equivalent, 48·06.

This is prepared by uniting carbonic acid gas with ammoniacal gas.

The carbonate of ammonia of the shops is not really the carbonate; it is the sesquicarbonate ( $2\text{NH}_4\text{O}, 3\text{CO}_2$ ). This is prepared by subliming carbonate of lime (chalk) and chloride of ammonium; a double decomposition results, giving sesquicarbonate of ammonia and chloride of calcium. It is a white, semi-transparent, pungent solid, which is converted into the bicarbonate of ammonia ( $\text{NH}_4\text{O}, 2\text{CO}_2$ ) by exposure, owing to the escape of ammonia. The sesquicarbonate is soluble in water, but insoluble in alcohol; has an alkaline reaction, an ammoniacal odour, and an acrid, hot, alkaline taste.

*Sulphate of Ammonia*.—Formula,  $\text{NH}_4\text{O}, \text{SO}_3 + \text{HO}$ ; equivalent, 75·06. This is obtained by neutralizing carbonate of ammonia, or coal-gas liquor, with sulphuric acid. It is soluble in water, and crystallizes in six-sided prisms.

*Nitrate of Ammonia*.—Formula,  $\text{NH}_4\text{O}, \text{NO}_5$ ; equivalent, 80·10. This is prepared by adding nitric acid to carbonate of ammonia. It is used for obtaining protoxide of nitrogen, (laughing gas.)

#### HALOID SALTS.

*Chloride of Ammonium; Sal Ammoniac*.—Formula,  $\text{NH}_4, \text{Cl}$ ; equivalent, 53·47.

Sal ammonia, was formerly got from Egypt; but it is now obtained in vast quantities as one of the products in preparing coal gas, and as a product also in the preparation of animal charcoal from bones, by the addition of hydrochloric acid; the free alkali is thus neutralized, and any salt of it that may exist is decomposed. The liquid is evaporated,

and the salt is then sublimed. It has a fibrous texture, a sharp saline taste, and is soluble in three parts cold and less boiling water.

*Tests.*—1. All the compounds of ammonia are volatile at high temperatures.

2. They either have an ammoniacal odour, or it can be produced by heating the salt with hydrate of lime.

3. Free ammonia is detected by forming a white cloud with chlorohydric acid gas.

## CLASS II.

### METALS OF THE ALKALINE EARTHS.

#### BARIUM.

Symbol,	.	.	.	.	.	.	.	Ba
Equivalent,	.	.	.	.	.	.	.	68.55

Barium is obtained from baryta, by exposing it to the action of a strong voltaic current in contact with mercury, and then distilling the amalgam thus formed. It is a white metal like silver, and readily oxidable in the air, but much less so than potassium or sodium.

#### COMPOUNDS OF BARIUM WITH OXYGEN.

Protoxide,	.	.	.	BaO	68.55 + 8 = 76.55
Peroxide,	.	.	.	BaO <sub>2</sub>	68.55 + 16 = 84.55

*Protoxide of Barium; Baryta.*—Equivalent, 76.55; formula, BaO. Baryta is the sole product of the oxidation of

barium in air or water; it is also obtained by decomposing the nitrate by heat. The latter is the way in which it is most frequently obtained. Obtained thus, it is a gray, spongy, anhydrous mass, with a caustic, alkaline taste, and a strong alkaline reaction. It has a very strong affinity for water, and when mixed with it slakes like lime, forming a hydrate.

The hydrate is a definite body; formula,  $\text{BaO}, \text{HO}$ . This is soluble in 20 parts cold and 2 parts boiling water. This solution is used as a reagent to detect the presence of sulphuric acid.

*Peroxide of Barium*.—Formula,  $\text{BaO}_2$ ; equivalent, 84.55. This is made by heating pure baryta in a copper vessel, and passing a stream of oxygen gas through it; it is also made by heating baryta with the chlorate of potash.

The peroxide of barium is used in preparing oxygenated water (bioxiide of hydrogen).

#### OXY-SALTS OF BARYTA.

Carbonate,	.	$\text{BaO}, \text{CO}_2$	$76.55+22$	$= 98.55$
Sulphate,	.	$\text{BaO}, \text{SO}_3$	$76.55+40$	$= 116.55$
Nitrate,	.	$\text{BaO}, \text{NO}_3$	$76.55+54.04$	$= 130.59$

*Carbonate of Baryta*.—Formula,  $\text{BaOCO}_2$ ; equivalent, 98.55. This salt occurs native; it is called *Witherite*. It may be prepared artificially, by adding an alkaline carbonate to the nitrate of baryta. It is a heavy white powder.

*Sulphate of Baryta*.—Formula,  $\text{BaO}, \text{SO}_3$ ; equivalent, 116.55. This is prepared by the addition of sulphuric acid to any soluble salt of baryta. It is the most insoluble salt known, requiring 40,000 times its weight of water to dissolve it. White lead is sometimes adulterated with it.

*Nitrate of Baryta*.—Formula,  $\text{BaONO}_3$ ; equivalent, 130.59.

Nitrate of baryta is prepared by adding nitric acid to a

solution of the sulphuret of barium in water; the water is decomposed, its oxygen goes to the barium, forming baryta, which then unites with the acid, while the hydrogen of the water unites with the sulphur, forming sulphuretted hydrogen. It is a soluble, anhydrous salt, crystallizing in square prisms.

#### HALOID SALTS OF BARIUM.

Chloride, . . .	BaCl	68·55+35·41=103·96
Bromide, . . .	BaBr	
Iodide, . . .	BaI	

*Chloride of Barium.*—Formula, BaCl; equivalent, 103·96. The chloride is prepared by adding chlorohydric acid to the sulphuret of barium; the chlorine unites with the barium, and the hydrogen with sulphur. It is white, crystallizing in square prisms, which contain two equivalents of water. It is used as a reagent.

The *bromide, iodide, &c.*, are prepared in the same way.

#### SULPHURETS OF BARIUM.

The sulphurets of barium are numerous.

*Protosulphuret of Barium.*—Formula, BaS; equivalent, 84·55. The protosulphuret is prepared by heating the sulphate of baryta with carbon; the latter removes all the oxygen, and the sulphur of the acid then unites with the barium, forming the sulphuret. This is a solid, of a yellowish-green colour, soluble in water, used to obtain the other compounds of barium, and also as a reagent.

*Tests for Barium.*—The soluble salts of baryta are poisonous; hence it is necessary to distinguish them. Its compounds can only be confounded with those of strontium.

1. Sulphuric acid gives the most insoluble salt known with baryta.

2. Chromic acid forms the insoluble chromate of baryta, which is of a lemon colour.

#### STRONTIUM.

Symbol,	.	.	.	.	Sr
Equivalent,	.	.	.	.	43.78

Strontium is found under the same conditions as barium. It was got originally near Strontian, in Scotland, and the earth containing it was therefore called strontianite.

Strontium resembles barium, and is obtained in the same way.

#### COMPOUNDS OF STRONTIUM WITH OXYGEN.

Protoxide,	.	.	.	SrO	43.78 + 8 = 51.78
Peroxide,	.	.	.	SrO <sub>2</sub>	43.78 + 16 = 59.78

*Protoxide of Strontium.*—Formula, SrO; equivalent, 51.78. This is best obtained by decomposing the nitrate by heat. It is a white powder, having a strong affinity for water, with which it slakes, forming a hydrate.

*Peroxide of Strontium.*—Formula, SrO<sub>2</sub>; equivalent, 59.78. The peroxide is prepared in the same way as the peroxide of barium.

#### OXY-SALTS OF STRONTIA.

Nitrate,	.	SrO, NO <sub>3</sub>	51.78 + 54.04 = 105.82
Sulphate,	.	SrO, SO <sub>4</sub>	
Carbonate,	.	SrO, CO <sub>3</sub>	
&c., &c.			

*Nitrate of Strontia.*—Formula, SrO, NO<sub>3</sub>; equivalent, 97.82. The nitrate is prepared by adding nitric acid to the sulphuret of strontium. It crystallizes in square prisms, and is soluble in water. It is much used by the pyrotechnist in making red fire. The *sulphate* and *carbonate* are analogous



to the corresponding salts of baryta, except that the sulphate of strontia requires only 4000 times its weight of water to dissolve it, while the sulphate of baryta requires 40,000 times its weight.

#### HALOID SALTS OF STRONTIUM.

Chloride,	.	.	SrCl	$43\cdot78 + 35\cdot41 = 79\cdot19$
Iodide,	.	.	SrI	
Bromide,	.	.	SrBr	
&c., &c.				

*Chloride of Strontium.*—Formula,  $\text{SrCl}$ ; equivalent, 79·19. The chloride is got by the addition of chlorohydric acid to the sulphuret of strontium. It crystallizes in colourless prisms, which contain 9 equivalents of water; they are soluble in water and alcohol.

*Sulphuret of Strontium.*—Formula,  $\text{SrS}$ ; equivalent, 59·78. The sulphuret is prepared in the same way as the sulphuret of barium, which it resembles in every respect.

*Tests for Strontium.*—Strontium and its preparations impart a beautiful blood-red colour to flame, which is sufficient to distinguish it under all circumstances.

#### CALCIUM.

Symbol,	.	.	.	.	.	.	.	Ca.
Equivalent,	.	.	.	.	.	.	.	20

Calcium is the metallic radical of lime. It is silver white, very oxidable, and is obtained by the same means as the preceding members of its class.

#### COMPOUNDS OF CALCIUM AND OXYGEN.

Protoxide,	.	.	.	.	$\text{CaO}$	$20 + 8 = 28$
Peroxide,	.	.	.	.	$\text{CaO}_2$	$20 + 16 = 36$

*Protoxide of Calcium; Lime.*—Formula,  $\text{CaO}$ ; equivalent, 28. Lime is got by heating the carbonate to redness, the carbonic acid is driven off, and the lime remains in a white amorphous mass. To obtain pure lime, pure calcareous spar must be used. The process is largely conducted all over the country in lime-kilns.

Lime is a white, brittle solid, with a specific gravity of 2.3. It is phosphorescent at high temperatures, and infusible except by the oxy-hydrogen blowpipe. It rapidly absorbs moisture, and evolves much heat in the process, becoming a hydrate ( $\text{CaO} + \text{HO}$ ); the process is called slaking. During the process much heat is evolved. This hydrate is soluble in water, much more so in cold than in warm water. Thus, 1 grain of lime requires 778 grains of water at  $60^\circ$  Fahrenheit, and 1270 grains of water at  $212^\circ$  Fahrenheit. Lime-water is prepared by agitating hydrate of lime with cold water, and then allowing the water to stand. Lime-water should be excluded from the air, because it absorbs carbonic acid and precipitates carbonate of lime.

Lime-water has an acrid, alkaline taste, and is used as a reagent.

*Peroxide of Calcium.*—Formula,  $\text{CaO}_2$ ; equivalent, 36. This is prepared in the same way as the peroxide of barium, which it resembles every way.

#### OXY-SALTS OF LIME.

Carbonate,	.	.	.	$\text{CaO}, \text{CO}_2$	$28 + 22 = 50$
Sulphate,	.	.	.	$\text{CaO}, \text{SO}_3$	$28 + 40 = 68$
Phosphates,	.	.	.	Polybasic.	
&c., &c.					

*Carbonate of Lime.*—Formula,  $\text{CaO}, \text{CO}_2$ ; equivalent, 50. This salt is found abundantly in all parts of the earth in amorphous masses called limestone. But it also exists in a crystallized form, as calcareous spar, and in a subcrystallized

form, as marble; of the latter there are many forms, from the purest Parian to the inferior saccharoidal.

Carbonate of lime is also found in solution in mineral springs; these are formed by rain and snow water (which contain much carbonic acid) percolating through the soil, and meeting carbonate of lime which they dissolve.

The beautiful carbonate of lime formations, stalagmites, and stalactites found in caves, are thus formed; the carbonic acid water dropping from the roof loses its excess of carbonic acid, and the water being no longer able to hold the carbonate of lime in solution, precipitates it.

*Sulphate of Lime.*—Formula,  $\text{CaO}, \text{SO}_3$ ; equivalent, 68. Sulphate of lime may be made by adding sulphuric acid to the carbonate; and, indeed, all the salts may be obtained by decomposing the carbonate. It occurs native in a crystalline form, which, when regular, confers on it the name of *selenite*. The sulphate is also called *plaster of Paris*, and *gypsum*. In all these natural forms, it contains 2 equivalents of water of crystallization.

It is slightly soluble in water, which takes up  $\frac{1}{800}$  of its weight at  $212^\circ$ ; from this solution crystals may be obtained, the same as those formed in nature; formula,  $\text{CaO}, \text{SO}_3 + 2\text{HO}$ .

When this salt is ground up and heated, it loses its water of crystallization, and becomes an anhydrous white powder. If this powder be mixed with water it will absorb it and form a hydrate, which becomes solid in a few minutes. On this account it is used for making casts.

*Phosphates.*—There are as many phosphates of lime as there are of soda. The tribasic phosphates, indicated by  $2\text{CaO}, \text{HO}, \text{PO}_5$ , and  $3\text{CaO}, \text{PO}_5$ , are formed when the corresponding soda salts are added to a solution of chloride of calcium. There are also mono, and bibasic salts.

The phosphates of lime exist in bones very abundantly.

## HALOID SALTS OF CALCIUM.

Chloride, . . . .	CaCl	20+35.41=55.41
Fluoride, . . . .	CaF	20+18.26=38.26
Bromide, Iodide, &c.		

*Chloride of Calcium.*—Formula,  $\text{CaCl}$ ; equivalent, 55.41. This salt is prepared by dissolving chalk or marble in chlorohydric acid; it crystallizes from the solution in colourless prisms, containing 6 equivalents of water. This water may be driven off by a strong heat, and an anhydrous white powder produced, which is most valuable for drying gases, and making freezing mixtures, owing to its great avidity for water. It is soluble in alcohol as well as water.

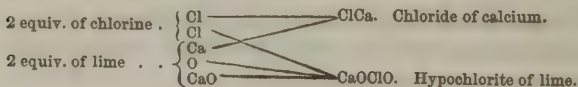
*Fluoride of Calcium.*—Formula,  $\text{CaF}$ ; equivalent, 38.26. This salt exists in nature as a beautiful crystalline mineral, called *fluor* or *Derbyshire spar*. It is only useful in obtaining fluohydric acid. The iodide, bromide, &c., are obtained as before.

## SULPHURETS OF CALCIUM.

There are 3 sulphurets, viz., the proto, bi, and penta sulphuret. The proto salt is got by igniting sulphate of lime with charcoal. The rest are obtained from it by boiling with sulphur.

*Chloride of Lime; Bleaching Salts.*—Formula,  $\text{CaCl} + \text{CaO}, \text{ClO}$ .

When chlorine gas is passed through hydrate of lime, a compound is produced, called bleaching salts, but which is chemically a mixture of chloride of calcium and hypochlorite of lime.



This a soft, whitish powder, soluble in 10 parts of cold water, and used as a bleaching agent.

*Tests for Calcium Compounds.*—1. Oxalic acid is the best test; but the acid should not be used per se, because, instead of having the oxalate of lime formed, we may have the oxalic acid decomposed into carbonic acid and carbonic oxide, and a carbonate thus formed instead of an oxalate, while carbonic oxide gas would be eliminated. To obviate this difficulty, the oxalate of ammonia may be used, so that the ammonia may neutralize the acid of the salt of lime to be tested. Thus, present the oxalate of ammonia to the nitrate of lime, and we get nitrate of ammonia and oxalate of lime. The precipitate, oxalate of lime, is white and very fine, resembling a cloud in the water; it is soluble in the acids.

2. Add the tribasic phosphate of soda to the chloride of calcium, and a very insoluble white precipitate is obtained. This phosphate of lime is remarkable for its large amount of base; its formula is said to be  $8\text{CaO} + 3\text{PO}_5$ .

## MAGNESIUM.

Symbol,	.	.	.	.	.	.	Mg
Equivalent,	.	.	.	.	.	.	12.67

The metal magnesium is got by decomposing the chloride, by means of potassium and heat, in a glass tube. Magnesium is white, brilliant, malleable, and fusible at a red heat. Heated in the open air or oxygen, it burns; the only product of the combustion is magnesia.

*Protoxide of Magnesium.*—Formula,  $\text{MgO}$ ; equivalent, 20.67. This body, commonly called magnesia, and calcined magnesia, is obtained by calcining the carbonate. It is a soft, light, white powder, having a very feeble affinity for water, requiring 5000 parts at  $60^\circ$ , and 36,000 parts at  $212^\circ$  for its solution. Magnesia does not affect test paper, but it neutralizes acids.

## OXY-SALTS OF MAGNESIA.

Carbonate, .	MgO, CO <sub>2</sub>	20·67+22=42·67
Sulphate, .	MgO, SO <sub>3</sub> +7HO	20·67+40+63=123·67
Phosphates,		
Silicates.		

*Carbonate of Magnesia.*—Formula, MgO, CO<sub>2</sub>; equivalent, 42·67. The neutral carbonate occurs native in crystals. The *magnesia alba* of the shops, is also a hydrated carbonate combined with a hydrate. It is prepared by adding carbonate of potassa to the sulphate of magnesia: the carbonate of magnesia is precipitated as a fine white powder, which is then dried. It is soluble in excess of carbonic acid, and is held suspended thus in Saratoga-water. Its formula is HO, MgO+HO, MgO, CO<sub>2</sub>.

*Sulphate of Magnesia.*—Formula, MgOSO<sub>3</sub>+7HO; equivalent, 123·67.

This body is known everywhere by the name of *Epsom salt*. It is prepared on a large scale from soapstone, which is a silicate of magnesia. The stone is first roasted to oxidize the iron it contains, and then treated with hot sulphuric acid. This forms sulphates of magnesia and iron, which are dissolved out by water; this solution is then treated with milk of lime, which precipitates both oxide of iron and sulphate of lime, leaving nothing but sulphate of magnesia in solution. This is transferred to iron vats, and allowed to crystallize. The crystals are four-sided pyramids, soluble in their own weight of cold water. It has a nauseous, bitter taste, and is used as a purgative.

Sulphate of magnesia is the type of a large class of metallic salts, as those of iron, copper, zinc, &c. Its constitution is indicated by the following formula, MgO, SO<sub>3</sub>, HO+6HO; the one equivalent of water is constitutional, and cannot be



driven off without destroying the salt; the other six equivalents of water may be lost, and affect nothing but its crystalline form.

The sulphate of magnesia may have its constitutional water substituted by another salt, and a double salt thus be formed, as the sulphate of magnesia and potassa. Formula,  $\text{MgO}, \text{SO}_3(\text{KO}, \text{SO}_3) + 6\text{HO}$ .

*Phosphates.*—The most remarkable of these is the *ammonio magnesian phosphate*, or as it is sometimes called, the triple phosphate. Formula,  $2\text{MgO}, \text{NH}_4\text{O}, \text{PO}_5 + 14\text{HO}$ . It is made by first adding the tribasic phosphate of soda ( $2\text{NaO}, \text{HO}, \text{PO}_5$ ) to the sulphate of magnesia, and afterwards adding ammonia or its carbonate. This salt sometimes constitutes urinary calculi.

*Silicates of Magnesia.*—These constitute the different varieties of soapstone, viz. : *Steatite*,  $\text{MgO}, \text{SiO}_3$ ; *Meerschaum*,  $\text{MgO}, \text{SiO}_3 + \text{HO}$ ; *Chrysolite*,  $3\text{MgO}, \text{SiO}_3$ ; also *Serpentine*, *Augite*, *Hornblende*, &c.

#### HALOID SALTS OF MAGNESIUM.

Chloride, . . .  $\text{MgCl} \quad 20.67 + 35.41 = 56.08$ .

Iodide, Bromide, &c.

Chloride,  $\text{MgCl}$ . Equivalent, 56.08.

This is prepared by dissolving magnesia in chlorohydric acid, then adding chloride of ammonium to the solution and evaporate; a double salt is obtained, but the chloride of ammonium may be sublimed, and leave the chloride of magnesium in a fused state. It is white, crystalline, and very soluble in water.

*Tests.*—The best test is to form the ammonio-magnesian phosphate by the addition of ammonia to a soluble phosphate of magnesia.

## CLASS III.

## METALS OF THE EARTHS PROPER.

## ALUMINUM.

Symbol, . . . . .	Al
Equivalent, . . . . .	13.69

Aluminum is the basis of alumina, which exists very abundantly in nature as a constituent part of clay. The metal is obtained from the chloride of aluminum by heating it with potassium.

It is got thus in a gray powder, or scales having a metallic lustre. Aluminum requires a very high temperature to melt it, but when heated in the air or oxygen, it burns most brilliantly, yielding alumina.

*Sesquioxide of Aluminum ; Alumina.*—Formula,  $\text{Al}_2\text{O}_3$ ; equivalent, 51.38.

Alumina, as has been said, is very abundant; it forms part of all primary rocks, being combined generally as *feldspar* (silicate of alumina and potassa) in granite. Granitic rocks become disintegrated by the action of air and moisture; the silicate of potassa being soluble is washed away, while the silicate of alumina, which is a very insoluble salt, analogous to glass, remains. This salt has the remarkable property of absorbing water and becoming a plastic mass, capable of being moulded to any shape. Hence it is used in the manufacture of pottery. Porcelain, and indeed all earthenwares, are composed of silicic acid, alumina, and water. When porcelain is first baked or dried, it is called biscuit-ware, which is opaque;

but this is coated with a varnish made of silicate of alumina and potassa (pure feldspar), which gives to the whole of it translucency.

Alumina is very readily obtained from alum by the addition of any alkali. Alum is a sulphate of alumina and potassa, and when the alkali is added it displaces the alumina, which is a feeble base. The precipitate is white, bulky, and gelatinous; this is washed, dried, and heated intensely. Thus got, it is white, tasteless, and coherent. It is a feeble base, and its salts have an acid reaction. Alumina is inferred from analogy to be a sesquioxide.

Alumina retains moisture very eagerly, and it is hence useful in retaining moisture in soils during long droughts.

#### OXY-SALTS OF ALUMINA.

Sulphate, . .  $\text{Al}_2\text{O}_3, 3\text{SO}_3 - 51.38 + 120 = 171.38$   
 Alums,

*Sulphate of Alumina.*—Formula,  $\text{Al}_2\text{O}_3, 3\text{SO}_3$ ; equivalent, 171.38.

Alumina has a very feeble affinity for acids; but if it be boiled for a long time with sulphuric acid, a solution is got which yields crystals of sulphate of alumina by evaporation.

The solution of this salt in water is decomposed by all the alkalies; it will unite with other salts, forming double ones.

*Alums; Sulphate of Alumina and Potassa.*—Formula,  $\text{Al}_2\text{O}_3, 3\text{SO}_3 + \text{K}_2\text{O}, \text{SO}_3 + 24\text{H}_2\text{O}$ ; equivalent, 474.57.

This salt, which is *common alum*, is manufactured on a large scale for commercial purposes from a clay containing sulphuret of iron. The sulphur is converted into sulphuric acid, which then unites with the iron and alumina, forming sulphate of alumina and iron; to this, chloride of potassium is added, which decomposes the iron salt, giving sulphate of potassa and chloride of iron, the former combining with sul-

phate of alumina. It is also made for chemical purposes by boiling sulphate of alumina in solution with sulphate of potassa.

The salt crystallizes out in octohedrons. It has a sweetish astringent taste, is soluble in 5 parts of water at  $60^{\circ}$ , and its own weight of boiling water.

The crystals contain 24 equivalents of water, which they lose by being heated, and fall into a white powder, called *alum exsiccatum*. If the heat be carried too far, the salt is decomposed, and nothing is left but nearly pure alumina.

Dried alum and sugar, carbonized in the open air, and then heated to redness out of the air, constitutes *Homborg's pyrophorus*.

There are two other alums besides the one just described, viz., *sulphate of alumina and soda*; formula,  $\text{Al}_2\text{O}_3, 3\text{SO}_3 + \text{NaO}, \text{SO}_3 + 24\text{HO}$ , and *sulphate of alumina and ammonia*; formula,  $\text{Al}_2\text{O}_3, 3\text{SO}_3 + \text{NH}_4\text{O}, \text{SO}_3 + 24\text{HO}$ .

These salts are both analogous to common alum, and are formed in the same way. Some of the salts of the metals proper are *isomorphous* with the alums, as

Iron Alum,	.	.	$\text{Fe}_2\text{O}_3, 3\text{SO}_3 + \text{KO}, \text{SO}_3 + 24\text{HO}$
Manganese Alum,	.	.	$\text{Mn}_2\text{O}_3, 3\text{SO}_3 + \text{KO}, \text{SO}_3 + 24\text{HO}$
Chrome Alum,	.	.	$\text{Cr}_2\text{O}_3, 3\text{SO}_3 + \text{KO}, \text{SO}_3 + 24\text{HO}$

*Tests for Aluminum Compounds.*—1. Alumina has an earthy smell when breathed on, and has a strong affinity for water, adhering to the tongue when placed on it.

2. Alumina will not form a carbonate; hence when a carbonate of potash or any alkali is added to a solution of alum, a precipitate of alumina is got, and the acid escapes by effervescence.

3. Alumina is precipitated from a solution of a salt, by caustic potash, or soda, and is redissolved by an excess of the precipitant.

4. Alumina forms permanent compounds with colouring matter, and is, therefore much used in dyeing. Add a solution of alum to a solution of any colouring matter, as cochineal, and then add carbonate of potassa; the alumina will be thrown down, carrying with it all the colouring matter.

5. Alumina is also tested by a blowpipe flame with nitrate of cobalt. It fuses and becomes blue.

## GLUCINUM.

Symbol,	.	.	.	.	.	.	.	Gl
Equivalent,	.	.	.	.	.	.	.	26·5

Glucinum is the basis of the earth glucina, so named because its salts are sweet.

*Sesquioxide of Glucinum.*—Formula,  $\text{Gl}_2\text{O}_3$ ; equivalent, 77. The sesquioxide, or glucina, as it is called, is found in the beryl, emerald, and many other precious stones, which are silicates. The earth is got from these by fusing with potassa. It is white, not having so strong an affinity for water as alumina, and distinguished from it by being soluble in an excess of carbonate of ammonia.

Its salts are analogous to those of alumina.

## YTTRIUM.

Symbol,	.	.	.	.	.	.	.	Y
Equivalent,	.	.	.	.	.	.	.	32·20

This metal is the basis of *yttria*, a rare earth found near Ytterby in Sweden.

*Protoxide; Yttria.*—Formula,  $\text{YO}$ ; equivalent, 40·20. This earth is white, and is distinguished from the others by not being soluble in excess of precipitant.

*Urbium* and *Thurbium* are two newly-discovered metals, found near the locality of Yttrium.

## ZIRCONIUM.

Symbol,	.	.	.	.	.	.	.	Zr
Equivalent,	.	.	.	.	.	.	.	33.62

Zirconium is the basis of the earth zirconia, which is found in the *Zircon* of Ceylon. The metal is obtained in a black powder, which may be boiled in water without being oxidized; but which, when heated in the open air, takes fire, giving zirconia.

*Sesquioxide, or Zirconia*.—Formula,  $\text{Zr}_2\text{O}_3$ ; equivalent, 91.24. This is an earthy substance resembling alumina, having no taste or odour, and insoluble in water.

## THORIUM.

Symbol,	.	.	.	.	.	.	.	Th
Equivalent,	.	.	.	.	.	.	.	59.89

Thorium is the basis of thoria, which exists in *thorite*, found in Norway. The metal is obtained in the form of a heavy metallic powder, with a leaden gray lustre. It is not oxidized by hot or cold water, but when heated in the open air it burns brilliantly.

*Protoxide, or Thoria*.—Formula,  $\text{ThO}$ ; equivalent, 67.89. This is a white, earthy, and very heavy body; specific gravity, 9.40.



## CLASS IV.

## METALS PROPER, WHOSE OXIDES ARE BASES.

## MANGANESE.

Symbol,	.	.	.	.	.	.	.	Mn
Equivalent,	.	.	.	.	.	.	.	27·67
Specific gravity,	.	.	.	.	.	.	.	8·
Melts at the highest heat of smith's forge.								

Manganese is not so abundant in nature as iron, but it is got associated with it in plants, animals, and iron ores. It is separated from it with difficulty. The metal is obtained by heating the bioxide intensely with carbonaceous matter, as oil, in a Hessian crucible, lined with charcoal.

It is a hard, grayish-white metal. It tarnishes by exposure, and by heating it to redness, owing to its uniting with oxygen. It decomposes water very slowly at common temperatures, but very rapidly if the temperature be considerably raised, or if sulphuric acid be added, becoming either the sesqui or bi-oxide.

## COMPOUNDS OF MANGANESE WITH OXYGEN.

Manganese forms no less than seven compounds with oxygen, but the sesquioxide, bioxide, and varvacite, are the only ones found in nature. Some of these compounds possess the property of feeble acids.

Protoxide, . . . . .	MnO	$27·67 + 8 = 35·67$
Sesquioxide, . . . . .	Mn <sub>2</sub> O <sub>3</sub>	$55·34 + 24 = 79·34$
Bioxide, . . . . .	MnO <sub>2</sub>	$27·67 + 16 = 43·67$
Red Oxide, . . . . .	Mn <sub>3</sub> O <sub>4</sub>	$83·01 + 32 = 115·01$
Varvacite, . . . . .	Mn <sub>4</sub> O <sub>7</sub>	$110·68 + 56 = 166·68$
Manganic Acid, . . . . .	MnO <sub>3</sub>	$27·67 + 24 = 51·67$
Permanganic Acid, . . . .	Mn <sub>2</sub> O <sub>7</sub>	$55·34 + 56 = 111·34$

*Protoxide of Manganese*.—Formula,  $\text{MnO}$ ; equivalent, 35·67. This is the most basic oxide.

It is obtained by passing a current of hydrogen gas over the bioxide at a bright red heat; the bioxide loses one equivalent of oxygen, and water is formed. It is of a green colour. It absorbs oxygen very rapidly when heated, or in the presence of an alkali.

*Sesquioxide of Manganese*.—Formula,  $\text{Mn}_2\text{O}_3$ ; equivalent, 79·34.

This oxide occurs native in the Hartz. It is also a residue in heating the bioxide to obtain oxygen. It is of a dark brown colour, and it is a very feeble base.

*Bioxide of Manganese*.—Formula,  $\text{MnO}_2$ ; equivalent, 43·67.

This is also called *per* and *black oxide*. It occurs in nature with other bodies, as silex, clay, &c.

It is prepared by heating the protoxide with nitre. It is of a black colour, is insoluble in water, and refuses to form salts.

It is used for obtaining oxygen, and in the process for obtaining chlorine; it is also used in the arts for the manufacture of glass.

*Red Oxide of Manganese*.—Formula,  $\text{Mn}_3\text{O}_4$ ; equivalent, 115·01.

This is a natural product. It may also be made by heating the protoxide, which absorbs oxygen, or by heating a higher oxide which will lose oxygen. It is the most permanent of the oxides of manganese. Fused with glass, it communicates to it a violet tint; it is also the cause of the colour of the amethyst.

*Varvacite*.—Formula,  $\text{Mn}_4\text{O}_7$ ; equivalent, 166·68.

This body is got only in nature. It was found originally in Warwickshire, in England, hence the name. It crystallizes in six-sided pyramids.

*Manganic Acid.*—Formula,  $\text{MnO}_3$ ; equivalent, 51.67. When the protoxide or bioxide of manganese is heated with nitrate of potassa, so that the latter is decomposed, manganic acid is formed, which then unites with the potassa, forming manganate of potassa. This was formerly called *chameleon mineral*, owing to the many changes of colour it undergoes when dissolved in water. It is a green solid body, very soluble in water; the solution yields green crystals by evaporation.

Manganic acid cannot be obtained uncombined. On the addition of water to this body the solution is first green, it then becomes blue, purple, and red; till finally, a brown flocculent precipitate is obtained, which is the hydrated peroxide.

The changes of colour are owing to the formation of the permanganate of potassa, which is red, and the mixture of red and green produces the intermediate colours.

*Permanganic Acid.*—Formula,  $\text{Mn}_2\text{O}_7$ ; equivalent, 111.34.

This is prepared by heating chameleon mineral, which gives permanganate of potassa. Baryta may be substituted for potassa, and the baryta removed by sulphuric acid. In this way the acid is obtained; it occurs in fine pink crystals, which are very unstable.

*Sulphate of Protoxide of Manganese.*—Formula,  $\text{MnO}, \text{SO}_3, \text{HO} + 6\text{HO}$ .

This is a rose-coloured soluble salt, isomorphous with sulphate of magnesia (Epsom salt); both have one equivalent of constitutional water, and six equivalents of water of crystallization. It is used in dyeing to prepare brown colours: this is done by precipitating the protoxide with an alkali; the protoxide is thus thrown on the cloth, and rapidly becomes brown by absorbing more oxygen from the air.

*Carbonate of Protoxide of Manganese.*—Formula,  $\text{MnO}, \text{CO}_2$ .

This is prepared by adding the carbonate of potassa to a solution of the protochloride.

*Protochloride of Manganese*.—Formula,  $Mn, Cl$ .

This remains after obtaining chlorine by the action of chlorohydric acid on the bioxide. It crystallizes in rose-coloured crystals, which contain four equivalents of water.

*Tests*.—1. Ammonia throws down a precipitate which becomes flesh-coloured, and which is insoluble in excess of precipitant.

2. The formation of chameleon mineral is the best test. Manganese has been detected by this in the blood.

3. Manganese fused with borax under the blowpipe gives a bead of an amethystine colour.

## IRON.

Symbol,	.	.	.	.	.	.	.	Fe
Equivalent,	.	.	.	.	.	.	.	27.14
Specific Gravity,	.	.	.	.	.	.	.	7.79
Pure iron is fusible at the highest heat of smith's forge.								
Cast iron melts at 2786°.								

Iron has been known for ages; and is now indispensable to the necessities and luxuries of man. Pure iron is very rarely found, but it is got in association with many other substances, particularly with oxygen and sulphur, forming ores.

The ores of iron are at least thirty in number; the most abundant and important are the oxides and sulphurets. Nearly all bodies contain iron, but those only which contain 20 per cent. are called ores. The ores are called by various names, as *hematite*, *pipe ore*, *iron pyrites* or *fool's gold*, and *loadstone*, beside many others. Loadstone or magnetic ore is very abundant in New Jersey and Missouri.

Iron is obtained from its ores by heating them intensely in a furnace with charcoal and limestone; the materials being put in, in successive layers, and the heat kept up by a blast

of hot or cold air. The carbonaceous matter removes the oxygen, and the limestone removes the sand. A fused mass is formed, the iron being the heaviest sinks, carbonic acid and carbonic oxide escape (the latter burning with a blue blaze), while the silicate of lime floats on top, and forms a slag. (This silicate is a glass made green by the presence of iron.)

The iron is now got by tapping the furnace; it is cast-iron, and the pieces are called pigs. It is brittle, pseudo-crystalline, and grayish; the impurities are silica, manganese, carbon, &c.; in reality it is a carburet of iron.

This iron is now heated in a puddling furnace; and a current of air is allowed to play on its surface; the carbon is oxidized, and the iron becoming purer and purer is rendered less and less fusible, until it finally becomes an inspissated mass. This is now taken out and submitted to the blows of a tilt hammer; the more fusible portions are forced out, and large masses of malleable iron are thus formed, which are called blooms.

These blooms are again heated and submitted to a powerful compression between rollers, and become bar or rod iron. This is the purest iron of commerce, although it is still impure. It is fibrous, ductile, and capable of being welded. Constant motion or vibration for a long time, causes it to assume a crystalline form, and it becomes brittle and liable to fracture.

Pure iron has a white colour and perfect metallic lustre. It is soft and very tough; it is the most tenacious of the metals. It is not changed in dry air, but absorbs oxygen when moisture is present, and becomes a sesquioxide. It is very rapidly changed by the action of an acid and moisture.

*Impalpable Powder of Iron.*—This is called pyrophoric iron. It is obtained by heating the sesqui or protoxide in a

porcelain tube, and passing a stream of hydrogen gas over it. The oxygen is removed, water is formed, and perfectly pure iron remains. This will burn very readily when heated, and the result of the combustion is the sesquioxide. It is used in medicine.

#### OXY-COMPOUNDS OF IRON.

Protoxide, . . . . .	FeO	27·14+ 8= 35·14
Sesquioxide, . . . . .	Fe <sub>2</sub> O <sub>3</sub>	54·28+24= 78·28
Black or Magnetic Oxide, . . . . .	Fe <sub>3</sub> O <sub>4</sub> FeO	81·42+32=113·42
Ferric Acid, . . . . .	FeO <sub>3</sub>	27·14+24= 51·14

*Protoxide of Iron.*—Formula, FeO ; equivalent, 35·14.

The protoxide cannot be prepared directly from oxygen and iron. It is got indirectly by adding an alkali to a solution of a protosalt as the protosulphate. The protoxide is precipitated as a hydrate. This is a dirty, greenish powder, which rapidly changes from green to brown, owing to its conversion into the sesquioxide.

It is a powerful base, neutralizing acids and forming salts, isomorphous with those of magnesia.

*Sesqui or Peroxide of Iron.*—Formula, Fe<sub>2</sub>O<sub>3</sub> ; equivalent, 78·28.

This occurs native as red and brown hæmatites. It is obtained also by heating or exposing iron to the action of air and moisture. It is of a foxy brown colour, which is characteristic of it and all the persalts. It is basic, but not so much so as the protoxide. It may be obtained very pure by precipitating from the sesquisulphate by means of an alkali or its carbonate. Iron rust is the sesquioxide.

*Black or Magnetic Oxide ; Loadstone.*—Formula, Fe<sub>3</sub>O<sub>4</sub>, FeO ; equivalent, 113·42.

This compound is composed of two oxides, viz., the sesqui and protoxide. It occurs naturally in regular octohedrons,



and is not only magnetic itself, but it confers that property on other bodies.

It may be formed artificially by heating iron to a high temperature in moist air. It does not form salts.

*Ferric Acid*.—Formula,  $\text{FeO}_3$ ; equivalent, 51.14.

This acid, like manganic, cannot exist separately. It is obtained by heating a pro or sesquioxide of iron with nitrate of potassa; the nitre is decomposed, its oxygen unites with iron, forming ferric acid, and this then unites with the potassa, forming ferrate of potassa. This salt is of an amethystine red colour, and soluble in water; the solution at first is red, but it changes rapidly to brown, owing to the loss of oxygen and the consequent precipitation of the sesquioxide.

#### OXY-SALTS OF IRON.

Sulphate, . . .	$\text{FeO}, \text{SO}_3, \text{HO}+6\text{HO}$	$35.14+40+63=138.14$
Sesqui or Persulphate, . . .	$\text{Fe}_2\text{O}_3, 3\text{SO}_3$	
Nitrate, . . . . .	$\text{FeO}, \text{NO}_5$	$35.14+54.06=89.20$
Pernitrate, . . . . .	$\text{Fe}_2\text{O}_3, 3\text{NO}_5$	
Carbonate, . . . . .	$\text{FeO}, \text{CO}_2, \text{HO}$	

*Sulphate of Protoxide of Iron*.—Formula,  $\text{FeO}, \text{SO}_3, \text{HO}+6\text{HO}$ .

This salt, commonly called *copperas*, or *green vitriol*, is obtained when iron is submitted to the action of sulphuric acid and water; the salt remains in solution, which by evaporation yields green crystals. It is prepared on a large scale by exposing iron pyrites to the combined action of air and moisture.

The constitution of this salt is precisely analogous to that of sulphate of magnesia, with which it is isomorphous. It is soluble in twice its weight of water, giving a green solution, which is characteristic of all the protosalts of iron.

This salt effloresces by exposure; and by absorbing oxygen, a sesquioxide is also formed on its surface, in the form of a foxy powder.

*Sesqui or Persulphate of Iron.*—Formula,  $\text{Fe}_2\text{O}_3, 3\text{SO}_3$ .

This is obtained by adding sulphuric acid to the sesquioxide; three equivalents of acid unite to one equivalent of the sesquioxide to form a neutral salt. It is in the form of a brownish amorphous powder, slowly soluble in water. With sulphate of potassa, &c., it forms double salts, which are *iron alums*. An alkali, or even an alkaline carbonate added to its solution, gives a precipitate of the sesquioxide, because carbonic acid cannot unite with a peroxide.

*Nitrate of Protoxide of Iron.*—Formula,  $\text{FeO}, \text{NO}_5$ ; equivalent, 89.20.

When iron is treated with dilute nitric acid, a nitrate of the protoxide is obtained. The iron is oxidized at the expense of the nitric acid, and then unites with some undecomposed acid. It is a green crystalline body; but it cannot be kept, on account of its rapidly absorbing oxygen.

*Per or Sesquinitrate.*—Formula,  $\text{Fe}_2\text{O}_3, 3\text{NO}_5$ .

This is prepared by treating iron with an excess of nitric acid. It is permanent, and of a brown colour.

*Carbonate of Protoxide of Iron.*—Formula,  $\text{FeO}, \text{CO}_2 + \text{HO}$ .

The proto carbonate is made by adding the carbonate of soda in solution, to a solution of the protosulphate of iron; double decomposition ensues, and the protocarbonate of iron is precipitated in the form of a whitish-green powder. But the iron very rapidly absorbs more oxygen, and is converted into the sesquioxide, while the carbonic acid, which cannot combine with this oxide, escapes.

It is, however, said to be prevented from passing into higher states of oxidation, by incorporating it with honey or sugar as soon as formed. It is a hydrate.

## HALOID SALTS OF IRON.

Protochloride,	.	FeCl	27·14+ 35·41= 62·55
Sesquichloride,	.	Fe <sub>2</sub> Cl <sub>3</sub>	
Protiodide,	.	FeI	27·14+126·36=153·50
Sesquiodide,	.	Fe <sub>2</sub> I <sub>3</sub>	
Cyanides.			

*Protochloride*.—Formula, FeCl; equivalent, 62·55.

Iron in a state of fine division will take fire when thrown in chlorine gas, and a protochloride of iron is formed. It is also made by dissolving iron in chlorohydric acid; the solution yields green crystals, soluble in water, and deliquescent, which rapidly peroxidize.

*Sesquichloride*.—Formula, Fe<sub>2</sub>Cl<sub>3</sub>.

This is made by adding a mixture of two parts chlorohydric acid, and one part nitric acid (aqua regia), to metallic iron. It is brown, and yields crystals by evaporation.

*Protiodide*.—Formula, FeI; equivalent, 153·50.

This salt is made by heating an excess of iron in a solution of iodine. It is a green solution, very difficult to keep, unless incorporated with sugar. Iron wire introduced in the bottle, preserves it slightly. It is much used in medicine.

*Sesquiodide*.—Formula, Fe<sub>2</sub>I<sub>3</sub>.

This is made by heating iron in excess of iodine. It is brown and permanent.

## SULPHURETS OF IRON.

Iron is found in combination with sulphur, forming the native sulphuret called *iron pyrites*. This is a hard solid, of a yellow colour. It is chemically the *bisulphuret*. Formula, FeS<sub>2</sub>. When this is heated, it loses one half an equivalent of sulphur, and is converted into the *sesquisulphuret*, Fe<sub>2</sub>S<sub>3</sub>.

*Protosulphuret*.—FeS. This is obtained by heating the

bisulphate with carbon, or by burning red hot iron in the vapour of sulphur. It is a black brittle solid, used principally for making sulphuretted hydrogen, which is done by the addition to it of sulphuric acid and water. We can see by this why sulphuretted hydrogen, which is one of the tests for iron, will not precipitate iron from a salt. For if we use, for instance, the sulphate, and pass a current of sulphuretted hydrogen through it, the sulphuric acid, the moment it is liberated, will decompose the sulphuret of iron as fast as it is formed; hence, to obtain the precipitate, we use the sulphur in combination, viz., as sulphuret of ammonium or potassium. Potassa or ammonia will be formed when a sulphuret of their metals is added to an oxy-salt of iron, and the alkali thus formed will neutralize the acid of the salt. This is another method of forming protosulphuret of iron. By symbols; add SK to  $\text{FeO}$ ,  $\text{SO}_3$ , and we will get  $\text{FeS}$ , and  $\text{KO}$ ,  $\text{SO}_3$ .

#### COMPLEX OR DOUBLE CYANIDES.

Cyanogen is, as we have seen, a compound body, acting as a simple one, like chlorine. When iron is presented directly to it, there is no change; but when the cyanogen is in combination with an alkaline metal, and the iron in the form of a protosalt, a decomposition will result, giving a protocyanide of iron. This, however, is not permanent, because some of the iron is oxidized and the cyanogen is then left in combination with more iron. These are simple cases, and differ very much from the following.

*Ferrocyanide of Potassium; Yellow Prussiate of Potash.*—Formula,  $\text{Fe}$ ,  $\text{Cy}_3$ ,  $2\text{K}$  or  $\text{Fe}$ ,  $(\text{C}_6 \text{N}_3)$ ,  $2\text{K}$ .

The term yellow prussiate of potash is improper, because the compound contains neither prussic acid nor potassa.

This salt is manufactured on a large scale by fusing refuse animal matter, as old leather, bones, hair, &c., &c., with car-

bonate of potash and iron in a large iron vessel. Cyanide of potassium is first formed, which then uniting with iron, forms ferrocyanide of potassium. The salt is then dissolved out, and the solution yields beautiful large yellow octohedral crystals, soluble in water, but insoluble in alcohol.

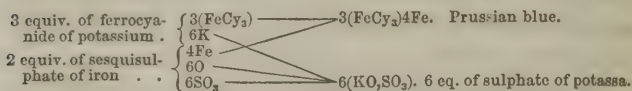
It is prepared in the laboratory by heating the cyanide of potassium with iron, in the presence of water: the iron unites with some cyanogen, giving cyanide of iron, which having a strong tendency to combine with other cyanides, unites with two equivalents of cyanide of potassium, and the salt formed is the double cyanide of iron and potassium; its formula is  $\text{FeCy} + 2\text{KCy}$ .

The above are the views entertained of this body on the supposition of its being a double salt; but if this were the case, the iron could be very readily detected in it, as in other iron salts, by tannic acid, and other reagents. But iron cannot be detected in the present salt by any known test; hence it is inferred that it must have a different grouping from that of double salts. Again, cyanogen in all its compounds forms combinations which are very poisonous, but the salts of this group are totally inert. For the above and other reasons, this compound has been considered as peculiar; viz.: that the iron enters more intimately into combination with the cyanogen, forming a compound radical, which is bibasic, and performs all the functions of an element. The compound radical is called *ferrocyanogen*; its formula is  $\text{FeCy}_3$ . The formula then for ferrocyanide of potassium is that which has been placed at first, viz.,  $\text{FeCy}_3, 2\text{K}$ . Ferrocyanogen has not been isolated.

*Ferrocyanide of Iron; Prussian Blue.*—Formula,  $3(\text{FeCy}_3), 4\text{Fe}$  or  $\text{Fe}_3\text{Cy}_9, 4\text{Fe}$ .

Prussian blue is made by adding ferrocyanide of potassium in solution to a sesquisalt of iron, as the sesquisulphate.

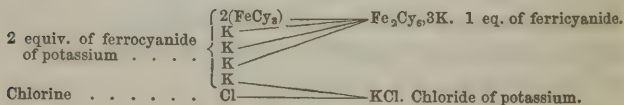
Three equivalents of the ferrocyanide act on two equivalents of the sesquisulphate.



This salt is a bulky precipitate, of an intense blue. When dry, it is hard, resembling indigo. It is insoluble in water. Its colour is destroyed by alkalies, which dissolve out a ferrocyanide, leaving oxide of iron. It is used as a pigment.

*Ferricyanide of Potassium ; Red Prussiate of Potassa.*—Formula ( $\text{Fe}_2\text{Cy}_6$ ), 3K.

This salt is prepared by passing a stream of chlorine gas through a solution of the ferrocyanide; the solution becomes red, and on evaporation yields a red crystalline salt, which is ferricyanide of potassium. Two equivalents of the ferrocyanide lose one equivalent of potassium to the chlorine, forming chloride of potassium, while the three equivalents of potassium left enter into combination with two of ferrocyanogen, which two equivalents are supposed to be another compound radical, called *ferricyanogen*, which is tribasic. Its formula is  $\text{Fe}_2\text{Cy}_6$ , or  $\text{Fe}_2\text{C}_{12}\text{N}_6$ .



This salt is regularly crystalline, beautifully red, permanent in the air and soluble in water.

*Ferricyanide of Iron ; Turnbull's Blue.*—Formula,  $\text{Fe}_2\text{Cy}_6$ , 3Fe.

Turnbull's blue is prepared by adding the ferricyanide of iron to a solution of a protosalt, as the protosulphate; the iron takes the place of the potassium. Thus, by symbols: Add



$\text{FeOSO}_3$  to  $\text{Fe}_2\text{Cy}_6$ ,  $3\text{K}$ , and we get  $\text{Fe}_2\text{Cy}_6$ ,  $3\text{Fe}$ , and  $\text{KOSO}_3$ . Turnbull's blue has a brighter tint than Prussian blue.

*Tests.*—1. The proto are distinguished from the sesquisalts by the former being green, the latter brown.

2. A protosalt precipitates Turnbull's blue by the addition of red prussiate or ferricyanide of potassium. A sesquisalt gives Prussian blue by the addition of ferrocyanide of potassium (yellow prussiate). As the per or sesquisalts are the more permanent ones, it is better to convert the proto into sesquisalts, and test with ferrocyanide of potassium for Prussian blue.

3. Sulphocyanide of potassium gives a blood-red precipitate with a sesquisalt of iron; but although this colour is very intense, it is destroyed by very little dilution. It is sulphocyanide of iron.

4. Tannic acid, or infusion of galls, gives a dense blue-black precipitate with the sesquisalts of iron, and a whitish precipitate with the protosalts. The former, the tannate of the sesquioxide, is the basis of writing ink. The tannic acid of kino gives a green-black precipitate with the sesquisalts. When the protochloride of tin, or any protosalt of it, is added to ink, it is decolorized, by the tin abstracting half an equivalent of oxygen from the sesquioxide and converting it into the protoxide.

5. Sulphuretted hydrogen, per se, will not precipitate a sulphuret of iron, but it will when in combination with an alkali; hence sulphuret of ammonium is used as a test. Both the proto and persalts are precipitated as black sulphurets.

6. Alkalies precipitate the greenish protoxide from the protosalts, and the same alkalies or their carbonates precipitate the brown sesquioxide from the persalts.

7. The changes of colour from red to brown that ferrate of potash undergoes in solution, are also a test.

## ZINC.

Symbol,	. . . . .	Zn
Equivalent,	. . . . .	33.
Specific gravity,	. . . . .	6.86 to 7.10
Melts at	. . . . .	773°

Zinc is found associated with cadmium as a carbonate, called *calamine*, or lapis calaminaris, and with sulphur, called zinc blende. It is also found associated with silica, and this, on account of its capability of becoming electrical, is called electric calamine.

The state of New Jersey affords much zinc from an ore called the red oxide.

Metallic zinc may be obtained from any of these sources by exposing them to a red heat with carbon. This has to be done out of the air, because the zinc volatilizes at 773°, and seizes oxygen, forming the white oxide. The process is, therefore, conducted in a large air-tight crucible, having a pipe leading from its bottom into a vessel filled with water. Heat is applied; the vapours of zinc rise, and are forced down by their own pressure through the pipe into the water.

The process is called *distillatio per decensam*. The zinc thus obtained is full of impurities; among which, the most prominent is arsenic, from which it may be purified by redistillation.

Zinc, when pure, is white, crystalline, and brittle at low and high temperatures, but malleable and ductile at 300°. Its specific gravity is about 7. It burns with a blue light at about 770° to 800°, and the result of the combustion is protoxide of zinc. It has a strong affinity for oxygen, and displaces the hydrogen of water from its oxygen in that body; the decomposition takes place very rapidly when an acid is present.

## OXY-COMPOUNDS OF ZINC.

Protoxide,	. .	$\text{ZnO}$	$33+8=41$
Sulphate,	. .	$\text{ZnOSO}_3+7\text{HO}$	$41+103=144$
Carbonate,	. .	$\text{ZnOCO}_2$	$41+22=63$

*Protoxide of Zinc.*—Formula,  $\text{ZnO}$ ; equivalent, 41.

This is the only known oxide. It may be got by burning metallic zinc; got thus, it is a beautiful snow-like substance, formerly called nihil alba, philosopher's wool, &c. It may also be obtained by precipitation from the sulphate by means of an alkali; in this way it is a hydrate. It is the only basic oxide, and it forms salts isomorphous with those of magnesia. It is white, tasteless, and insoluble in water.

*Sulphate of Protoxide.*—Formula,  $\text{ZnO}, \text{SO}_3, \text{HO}+6\text{HO}$ ; equivalent, 144.

This salt, which is commonly known by the name of *white vitriol*, is readily made by adding sulphuric acid to zinc, in the presence of water.

Crystals are obtained resembling Epsom salt, soluble in  $2\frac{1}{2}$  parts of cold water. They have an astringent styptic taste. By the addition of an alkali to a solution of the sulphate, a hydrated protoxide is obtained resembling magnesia, but the precipitated oxide of zinc is soluble in excess of the alkali, while magnesia is not.

*Carbonate of Protoxide of Zinc.*—Formula,  $\text{ZnO}, \text{CO}_2+\text{HO}$ .

This is prepared by adding a carbonate of an alkali to a solution of the sulphate; double decomposition takes place, resulting in the precipitation of the carbonate. It also occurs native, as calamine. It resembles magnesia alba, both being hydrated carbonates.

*Chloride of Zinc.*—Formula,  $\text{ZnCl}$ ; equivalent, 68.41.

This compound is formed by burning zinc filings in chlo-

rine gas, or by dissolving zinc in chlorohydric acid. It is colourless, fusible at  $212^{\circ}$ , and has a soft consistence at common temperatures, hence called butter of zinc.

*Sulphuret of Zinc.*— $\text{ZnS}$ ; equivalent, 49.

This is formed by adding a solution of sulphuretted hydrogen to any salt of zinc. It also occurs naturally under the name of *zinc blende*.

*Tests.*—1. Any of the alkalies precipitates the hydrated protoxide from a salt of zinc, which is white, and soluble in excess of the precipitant. Magnesia, with which it is isomorphous, and only liable to be confounded, is not soluble in excess of precipitant.

#### CADMIUM.

Symbol, . . . . .	Cd
Equivalent, . . . . .	55.74
Specific gravity, . . . . .	8.70
Melts at . . . . .	$442^{\circ}$

Cadmium is found associated with zinc. During the reduction of calamine, the cadmium, which is very volatile, flies off in vapour, and collects in the roof of the crucible. It is got from this.

Cadmium is akin to zinc; it is white, like tin, fuses at  $500^{\circ}$ , and is the most volatile of the metals except mercury. It is ductile and malleable, and when heated, burns. Its proper solvent is nitric acid. When bent, cadmium emits a cry or noise resembling that made by bending tin; the noise is due to the disruption of little crystals in the interior.

#### COMPOUNDS OF CADMIUM.

Protoxide, . . . . .	$\text{CdO}$	$55.74 + 8 = 63.74$
Sulphate, . . . . .	$\text{CdO}, \text{SO}_4 + 4\text{HO}$	
Chloride, . . . . .	$\text{CdCl}$	$55.74 + 35.41 = 91.15$
Sulphuret, . . . . .	$\text{CdS}$	$55.74 + 16 = 71.74$

*Protoxide of Cadmium.*—Formula,  $\text{CdO}$ ; equivalent, 63·74.

This is made by burning cadmium in the air, or by igniting the nitrate. Instead of being white like the protoxide of zinc, it is brown, and is thus distinguished. Like zinc, cadmium displaces hydrogen from water, especially in the presence of sulphuric acid.

*Sulphate of Cadmium.*—Formula,  $\text{CdO}, \text{SO}_3 + 4\text{HO}$ .

This is prepared by dissolving the oxide in sulphuric acid. It is soluble in water, and forms double salts.

*Chloride of Cadmium.*—Formula,  $\text{CdCl}$ ; equivalent, 91·15.

Made by dissolving the oxide in chlorohydric acid. It is soluble and crystalline.

*Sulphuret of Cadmium.*—Formula,  $\text{CdS}$ ; equivalent, 71·74.

This is prepared by passing sulphuretted hydrogen through a solution of the sulphate. It is bright yellow.

*Tests.*—1. Sulphuretted hydrogen precipitates the yellow sulphuret, while the sulphuret of zinc is white. Sulphuret of cadmium resembles the sulphuret of arsenic very much, but the latter is soluble in excess of potassa, while the former is not.

## COBALT.

Symbol, . . . . .	Co
Equivalent, . . . . .	29·52
Specific gravity, . . . . .	8·54
Melts at the highest heat of a smith's forge.	

Cobalt is found associated with nickel in combination with arsenic. It is got by roasting the arseniuret in a reverberatory furnace; the oxide is thus got, and this is then converted into the oxalate by being dissolved in oxalic acid; the oxalate

is then heated to a white heat in a crucible lined with charcoal.

Cobalt is a white brittle metal, undergoing very little change in the air, and but feebly acted on by sulphuric and chlorohydric acids. When pure it is not magnetic. It has two oxides.

#### COMPOUNDS OF COBALT.

Protoxide, . . . .	CoO	29.52 + 8 = 37.52
Sesquioxide, . . . .	Co <sub>2</sub> O <sub>3</sub>	58.04 + 24 = 82.04
Sulphate, . . . .	CoO, SO <sub>3</sub> + 7HO.	
Carbonate,		
Chloride, . . . .	CoCl	29.52 + 35.41 = 64.93

*Protoxide of Cobalt.*—Formula, CoO; equivalent, 37.52.

This is prepared by precipitating the sulphate with carbonate of soda. It is an ash-coloured powder, and is the basis of all the salts of cobalt.

By the addition of an alkali to a salt of cobalt, the hydrated protoxide is precipitated as a beautiful blue powder, which ultimately becomes red.

*Sesquioxide of Cobalt.*—Formula, Co<sub>2</sub>O<sub>3</sub>; equivalent, 82.04.

This is prepared by adding hypochlorite of lime to the chloride of cobalt. It is a black hydrate, insoluble, and does not form salts.

*Sulphate of Cobalt.*—CoOSO<sub>3</sub> + 7HO.

This is prepared by digesting the oxide in sulphuric acid. Its crystals are red. It forms double salts, which contain only six equivalents of water. It is thus isomorphous with sulphate of magnesia.

*Carbonate of Cobalt.*—Formula, 3Co, HO + 2CoCO<sub>3</sub> + HO.

This is prepared by the addition of the carbonate of an alkali to a solution of the sulphate. It is a peach-blossom-



coloured precipitate; which is a mixture of the hydrate and carbonate, as seen by the formula.

*Chloride of Cobalt*.—Formula,  $\text{CoCl}$ ; equivalent, 64·93.

This is prepared by dissolving the oxide in chlorohydric acid. It yields a pink solution, and by evaporation pink crystals; these crystals are hydrated; but by drying they lose the water and become blue; they again become red by contact with water. This is the basis of sympathetic writing ink. Writing made with this is invisible, but on drying it before the fire it becomes blue; when removed from the fire it absorbs moisture and becomes colourless.

*Tests*.—1. The salts of cobalt are generally red.

2. The precipitate of the protoxide by means of an alkali is always blue. This blue precipitate is used for colouring glass blue; it also unites with silicic acid, forming a silicate which is beautifully blue, and constitutes *smaltz*, and the artificial *ultramarine* of miniature painters.

3. The chloride of cobalt in solution is red, but becomes blue by drying.

## NICKEL.

Symbol, . . . . .	Ni
Equivalent, . . . . .	29·57
Specific gravity, . . . . .	8·80
Melts at the highest heat of a smith's forge.	

Nickel is found in the same localities as cobalt, as in the Hartz, meteoric iron, &c. It exists principally as the arseniuret, which is yellowish-red, like copper ore, and hence called *kupfernickel* by the miners. It is prepared from the ore in the same way that cobalt is.

Nickel is white, hard, and magnetic. It is malleable and ductile; has a feeble affinity for oxygen, and hence displaces

hydrogen from water very slowly, and it is acted on but feebly by the acids. It forms two oxides.

## COMPOUNDS OF NICKEL.

Protoxide,	.	.	NiO	29·57 + 8 = 37·57
Sesquioxide,	.	.	Ni <sub>2</sub> O <sub>3</sub>	59·14 + 24 = 83·14
Sulphate,	.	.	NiO, SO <sub>3</sub> + 7HO	
Carbonate, &c.				
Chloride.				

*Protoxide of Nickel.*—Formula, NiO; equivalent, 37·57.

This is prepared by heating the nitrate to redness. Got thus, it is ash-gray, soluble in acids, and forming salts isomorphous with those of magnesia. It may be precipitated from a soluble salt by a caustic alkali as a hydrate, which is a beautiful apple-green powder. The protoxide forms salts, which are green.

*Sesquioxide of Nickel.*—Ni<sub>2</sub>O<sub>3</sub>; equivalent, 83·14.

This is prepared by adding bleaching salt to the chloride of nickel. It is black, and insoluble; it is not basic.

*Sulphate of Nickel.*—Formula, NiOSO<sub>3</sub> + 7HO.

This is prepared by digesting the protoxide in sulphuric acid. It forms green crystals, which contain 1 equivalent of constitutional water, and 6 equivalents of water of crystallization. It also forms double salts.

*Carbonate of Nickel.*—This is got by the addition of an alkaline carbonate to a solution of the sulphate. It is a green powder, which is a mixture of the hydrate and the carbonate.

*Chloride of Nickel.*—Formula, NiCl; equivalent, 64·98.

This is prepared by dissolving the oxide of nickel in chlorohydric acid. It is a green solution, yielding green crystals, which become yellow when dried.

*Tests.*—1. The salts of nickel are generally green.

2. The protoxide of nickel is precipitated from any of its

salts in solution by an alkali, as a beautiful apple-green hydrate.

3. Sulphuretted hydrogen gives a black sulphuret.

## COPPER.

Symbol,	.	.	.	.	.	.	.	Cu
Equivalent,	.	.	.	.	.	.	.	31·65
Specific gravity,	.	.	.	.	.	.	.	8·96
Melts at	.	.	.	.	.	.	.	1996°

Copper was known to the ancients; it was originally brought from the Island of Cyprus; hence the name *cuprum*.

Its ores are those principally formed by combinations with oxygen and sulphur, the great mineralizing agents of nature. Many of these ores are united to acids, and thus constitute natural salts.

Copper pyrites, in which the copper is associated with nickel, sulphur, &c., constitutes the English or Cornwall copper ore. The Lake Superior region of the United States, abounds in a red sandstone, in which copper ore of a greater or less purity is obtained.

It is also found in *malacite*, which is the natural carbonate.

The metal copper is obtained from its ores by first roasting them to get rid of other materials, and then heating the oxide thus produced to 2000° or 3000° F., with carbonaceous matter.

Copper is a brilliant red metal; it is malleable, ductile, a good conductor of heat and electricity, and melts at a bright red heat. On exposure, it tarnishes, and becomes coated with a very red rust; but if heated in the air, it becomes black.

## OXIDES OF COPPER.

Sub or dioxide,	.	.	Cu <sub>2</sub> O	63·30+8=71·30
Protoxide,	.	.	CuO	31·65+8=39·65

*Sub or Dioxide of Copper.*—Formula,  $\text{Cu}_2\text{O}$  ; equivalent, 71.80.

This is commonly called the *red oxide*. It is obtained by exposing metallic copper to the action of the air, or by exposing the protoxide to one equivalent of metallic copper and heating. In the latter case, the oxygen is divided between the two equivalents of copper, and both become the dioxide. It may also be got by adding copper to a solution of the sulphate, and thus obtaining a solution of the subsulphate, and then adding potassa; or by adding grape sugar and caustic potassa to a solution of the same salt: in either case the potassa precipitates the red or dioxide. This oxide communicates to glass a beautiful red tint.

*Protoxide of Copper.*—Formula,  $\text{CuO}$  ; equivalent, 39.65.

This, which is the *black oxide*, is obtained by heating metallic copper to a red heat in the air. It may also be got as a bluish-green hydrate by the addition of an alkali to any of its soluble salts; this becomes brown by driving off the water. It is soluble in acids, and forms salts isomorphous with those of magnesia.

#### OXY-SALTS OF COPPER.

Nitrate,	.	.	.	.	.	.	$\text{CuONO}_3 + 3\text{HO}$
Sulphate,	.	.	.	.	.	.	$\text{CuOSO}_3 + 5\text{HO}$
Carbonates.							

*Nitrate of Copper.*—Formula,  $\text{CuO}, \text{NO}_5 + 3\text{HO}$ .

Nitric acid is the proper solvent for copper, and when presented to it, it acts very violently. Part of the acid is decomposed, losing 3 equivalents of oxygen, which go to 3 equivalents of copper, forming the protoxide, which then unites with some undecomposed acid. It is got thus in solution, from which it crystallizes in beautiful blue crystals, containing 3 equivalents of water, and isomorphous with the nitrate of magnesia.

This salt, as well as all the other protosalts of copper, is acid in its reaction. Indeed the nitrate of copper is just as active as nitric acid would be diluted with 4 equivalents of water (that is, acid of specific gravity 1.42); the oxide of copper and 3 equivalents of water of crystallization only serving to dilute it.

This can be illustrated by acting on tin foil with some powdered nitrate of copper a little moistened; speedy and violent action results with the evolution of light and heat.

There is an insoluble *subnitrate* of copper.

*Sulphate of Copper*.—Formula,  $\text{CuO}, \text{SO}_3 + 5\text{HO}$ .

Metallic copper does not, like most of the other metals of this class, displace hydrogen from water, or at least its action is very feeble. Hence, to obtain a sulphate, sulphuric acid, very strong, must be added to the metal, and oxidation then takes place at the expense of some of the acid, and not the water; sulphurous acid gas is formed and liberated, while the oxide of copper thus formed unites with some undecomposed acid, forming the sulphate of copper. It remains in solution, from which it crystallizes by evaporation in oblique prisms of a beautiful blue colour.

The crystals contain 5 equivalents of water; they are isomorphous with sulphate of magnesia, which commonly contains 7 equivalents of water, but which may be made to contain 5 equivalents. The sulphate of copper, like the sulphate of magnesia, may have its one equivalent of constitutional water replaced by another salt, thus forming a double one. Thus, there is a double sulphate of copper and potassa; formula,  $\text{CuO}, \text{SO}_3 + \text{KO}, \text{SO}_3 + 6\text{HO}$ . The crystals of this salt are remarkable for not expanding equally in all directions when heated, and consequently their molecular arrangements being thus destroyed, they fall into an impalpable powder on being cooled.

When ammonia is added to a solution of the sulphate, a

precipitation of the protoxide is first obtained, but on continuing to add the ammonia, a beautiful purple compound is obtained, called ammoniated copper, which remains in solution, from which it will crystallize. Now the oxide of copper is not soluble in ammonia, for this result will only take place when an acid is present, hence the inference, that a double salt is obtained; which in the present case is sulphate of ammonia and copper.

There is a *subsulphate*, which is noticed under the head of dioxide of copper.

*Carbonates of Copper.*—Copper, in contact with any acid, and exposed to the air, becomes coated with a green substance, erroneously called verdigris. It is really a subcarbonate, and is partially soluble in water. Hydrated carbonate is got by adding carbonate of soda to a solution of the sulphate. Double decomposition takes place, and the hydrated carbonate is precipitated. This is used as a pigment; it is beautifully green; it is also partially soluble in water. Formula,  $\text{CuO}, \text{CO}_2 + \text{CuO}, \text{HO}$ .

*Acetates of Copper. Subacetate.*—Metallic copper cannot be presented to any body containing water and acetic acid, or to any body capable of undergoing acetous fermentation, without the subacetate being formed. This is proper *verdigris*. That of commerce is got by exposing plates of copper to the action of grapes, after the wine has been pressed from them.

*Neutral Acetate.*— $\text{CuO}, \text{C}_4\text{H}_3\text{O}_3 + \text{Ho}$ . This is prepared by dissolving verdigris in hot acetic acid; it is soluble in water and alcohol.

#### HALOID SALTS OF COPPER.

Dichloride,	.	.	.	$\text{Cu}_2\text{Cl}$	$63\cdot30 + 35\cdot41 = 98\cdot71$
Chloride,	.	.	.	$\text{CuCl}$	$31\cdot65 + 35\cdot41 = 67\cdot06$

*Dichloride.*—Formula,  $\text{Cu}_2\text{Cl}$ ; equivalent, 98·71.



This is obtained from the protochloride, by presenting to it the protochloride of tin, which removes one equivalent of chlorine from two of the protochloride of copper, and the dichloride is precipitated. It is white, as all the sub-salts of copper are. It may be readily proved to be a subchloride, by heating it with an alkali, by which means, a chloride of the metal of the alkali is obtained, and its oxygen goes to the copper, forming a sub or red oxide. This is a case of simple substitution.

*Chloride of Copper.*—Formula,  $\text{CuCl}$ ; equivalent, 67.06.

When metallic copper is introduced into chlorine gas, it takes fire spontaneously, and forms a compound, which is the protochloride. The same salt may also be obtained by the action of chlorohydric acid on metallic copper. It is got thus in solution, from which it crystallizes in beautiful green crystals, soluble in water and alcohol, and containing 2 equivalents of water of crystallization.

*Alloys of Copper* are much used in the arts. *Brass* consists of 100 parts copper, with about 30 per cent. of zinc. Gun metal and bell metal consist of 90 parts of copper, with 10 parts of tin. Bronze consists of 90 parts copper, 6 parts zinc, 3 parts tin, and 1 part lead.

*Tests.*—1. Any oxy-salt of copper, treated with ammonia, gives a beautiful blue solution, *cuprum ammoniacum*, which may be a sulphate, nitrate, carbonate, &c.

2. When any protein compound, as albumen, is presented to a protosalt of copper, in the presence of an alkali, the beautiful blue solution will be formed. When the albumen is added previous to the addition of the alkali, a precipitate is got of the albuminate of copper; this is what is formed when copper is taken into the stomach. If caustic potassa be added to this precipitate, a resolution will take place, which is beautifully blue.

3. The red oxide of copper is always produced when the protoxide is presented to any organic body, and heated; carbonic acid and water are formed, and the red oxide is precipitated. Thus, take the sulphate of copper in solution, add potassa, and the protoxide is precipitated; but by the addition of grape sugar, a resolution takes place, and the solution is blue. Now, by applying heat to this, the sugar is decomposed; its carbon and hydrogen seize some of the oxygen of the protoxide, and form carbonic acid and water, and the red oxide is precipitated, giving the whole fluid a bright red tinge.

4. Sulphuretted hydrogen alone precipitates the black sulphuret of copper. This is a good test in the absence of other metals.

5. In minute quantities, the ferrocyanide of potassium added to the salt, will give a copious brown precipitate, which is the ferrocyanide of copper.

6. Copper is precipitated in a metallic state, from a salt in solution, by iron, zinc, or lead. The blade of a penknife will do for this purpose. It will detect copper where ammonia will not.

#### BISMUTH.

Symbol,	. . . . .	Bi
Equivalent,	. . . . .	70.95
Specific gravity,	. . . . .	9.90
Melts at	. . . . .	497°

Bismuth occurs native, and in combination with sulphur, arsenic, iron, copper, &c. It may be obtained pure for chemical purposes by heating the nitrate.

It is a beautiful crystalline metal, with a steel-like lustre and a roseate blush. It undergoes little change by exposure; it is very fusible, melting at 500° F.; and when heated in

the open air, above  $500^{\circ}$ ; it takes fire and burns with a bluish-white flame, emitting copious fumes of the protoxide of bismuth. It is not acted on readily by sulphuric or chlorohydric acids, but nitric acid is its proper solvent.

A mixture of 8 parts of bismuth, 5 parts of lead, and 3 of tin, constitutes Rose's fusible metal; this melts at  $212^{\circ}$  F.

## COMPOUNDS OF BISMUTH.

Suboxide, . . .	$\text{Bi}_2\text{O}$	$141.90 + 8$	$= 149.90$
Protoxide, . . .	$\text{BiO}$	$70.95 + 8$	$= 78.95$
Chloride, . . .	$\text{BiCl}$	$70.94 + 35.41$	$= 106.35$
Nitrate, . . . .	$\text{BiO}, \text{NO}_5 + 3\text{HO}$		
Subnitrate, . . .	$3\text{BiO}, \text{NO}_5 + \text{HO}$		

*Suboxide of Bismuth.*—This is got by exposing the metal; it is of no consequence.

*Protoxide of Bismuth.*—Formula,  $\text{BiO}$ ; equivalent, 78.95.

This is prepared by burning the metal or heating the nitrate, and then driving off its nitric acid. It is the base of the oxy-salts. It is yellow.

*Chloride of Bismuth.*—Formula,  $\text{BiCl}$ ; equivalent, 106.35.

This is got by introducing bismuth in powder in chlorine gas; it takes fire spontaneously, and forms the chloride. It was formerly called *butter of bismuth*.

*Nitrate of Bismuth.*—Formula,  $\text{BiO}, \text{NO}_5 + 3\text{HO}$ .

This is prepared by adding nitric acid to metallic bismuth. It crystallizes in transparent colourless crystals. When these are thrown in water, they are decomposed; the salt is converted into a supernitrate, which remains in solution, and a *sub-nitrate*, which is precipitated. This latter is sometimes called *magistery* of bismuth, and was for a long time used as a cosmetic. It is soluble in a large excess of water. It is used as a tonic in medicine. Formula,  $3\text{BiO}, \text{NO}_5 + \text{Ho}$ .

When chloride of bismuth is thrown in water, the same result takes place, viz., the precipitation of the sub-chloride. This decomposition shows the powerful basic property of water.

*Tests.*—1. The precipitation of the sub-salts by the addition of water to the proto-salts, forms a good test.

2. Sulphuretted hydrogen has a very strong action on any salt of bismuth, forming whenever it meets bismuth, an intense brown precipitate of the sulphuret.

#### LEAD.

Symbol,	.	.	.	.	.	.	.	Pb
Equivalent,	.	.	.	.	.	.	.	103.56
Specific gravity,	.	.	.	.	.	.	.	11.45
Melts at	.	.	.	.	.	.	.	612°

Lead was well known to the ancients. It occurs in vast quantities in combination with sulphur; this native sulphuret is called *galena*. The metal is obtained by roasting the ore in a reverberatory furnace. Lead is bluish gray, and when recently cut, has a strong metallic lustre; it is soft, flexible, and inelastic; it has the least tenacity of all the metals. It melts at 612°, and contracts much on cooling. It is slowly changed by the action of the air, but in time it becomes coated with a grayish powder, called the suboxide, which is partially soluble in water, and poisonous.

The reason why drinking water, which is generally conveyed through lead pipes, is not poisonous, is because the water generally contains salts, the acids of which form insoluble salts with the oxide of lead. These are generally the sulphates and chlorides. Perfectly pure water will become poisonous by passing through lead pipes.

## COMPOUNDS OF LEAD.

Suboxide, . . . .	$\text{Pb}_2\text{O}$	$207\cdot12 + 8 = 215\cdot12$
Oxide, . . . .	$\text{PbO}$	$103\cdot56 + 8 = 111\cdot56$
Bioxide, . . . .	$\text{PbO}_2$	$103\cdot56 + 16 = 119\cdot56$
Minium, or Red Lead, $\text{PbO}$ , $\text{PbO}_2$		

## OXY-SALTS.

Nitrate, . . . .	$\text{PbO}$ , $\text{NO}_3$
Sulphate, . . . .	$\text{PbO}$ , $\text{SO}_3$
Carbonate, . . . .	$\text{PbO}$ , $\text{CO}_3$
Chromate, . . . .	$\text{PbO}$ , $\text{CrO}_4$
Acetate. . . .	$\text{PbO}$ , $\text{C}_4\text{H}_3\text{O}_3 + 3\text{HO}$
Tribasic Acetate, . . . .	$3\text{PbO}$ , $\text{C}_4\text{H}_3\text{O}_3 + \text{HO}$
&c., &c.	

## HALOID SALTS.

Chloride, . . . .	$\text{PbCl}$
Bromide, . . . .	$\text{PbBr}$
Iodide, . . . .	$\text{PbI}$

*Suboxide of Lead.*— $\text{Pb}_2\text{O}$ . This is made by heating dry oxalate of lead to redness; a mixture of carbonic acid and carbonic oxide escapes, and suboxide is left. It does not form salts.

*Protoxide of Lead.*—Formula,  $\text{PbO}$ ; equivalent, 111·56.

The protoxide of lead is well defined. It is prepared by heating lead, while a blast of air plays over its surface. It thus forms an orange-coloured scaly mass, called in commerce *massicot*. This is sometimes, however, partly fused, and becoming vitreous, it is called the *semi-vitrified oxide* of lead, or *litharge*. The process should be conducted in a reverberatory furnace. It is used in pharmacy for lead plaster, and in the arts for dyeing. Protoxide of lead is yellow, very heavy, and slightly soluble in water. It is the only basic oxide, and forms a large class of salts.

*Red Lead or Minium.*—Formula,  $\text{PbO}$ ,  $\text{PbO}_2$ .

When air is made to play over massicot at a considerable heat, without fusing, the red oxide or minium is obtained. It is only a mixture of the bi and protoxide. It is brilliant, red, and heavy.

*Bioxide of Lead.*—Formula,  $\text{PbO}_2$ ; equivalent, 119.56.

This is sometimes called the *puce-coloured oxide*, because it is the colour of a flea. It has also recently been called *plumbic acid*. It is obtained indirectly, by adding nitric acid to minium (which is a mixture of the bi and protoxide); a nitrate of the protoxide is obtained, which remains in solution, while the bioxide is precipitated.

*Nitrate of Lead.*—Formula,  $\text{PbO}$ ,  $\text{NO}_3$ .

This salt is very readily obtained by adding nitric acid to metallic lead. Part of the acid is decomposed, giving oxygen to the lead forming the protoxide, which then unites with some undecomposed nitric acid. It is soluble; the present salt and the acetates are the only soluble ones. All the other salts of lead may be most readily prepared from the nitrate.

It crystallizes in opaque anhydrous octahedrons. When a solution of this salt is boiled, with additional oxide of lead, a basic subnitrate is formed.

*Sulphate of Lead.*—Formula,  $\text{PbO}$ ,  $\text{SO}_3$ .

This salt is prepared by the addition of sulphate of soda to the nitrate of lead. It is white, and extremely insoluble.

*Chromate of Lead.*—Formula,  $\text{PbO}$ ,  $\text{CrO}_3$ .

This is prepared by the addition of chromate of potash to the nitrate of lead. It forms a beautiful yellow pigment.

*Acetate of Lead.*—Formula,  $\text{PbO}$ ,  $\text{C}_4\text{H}_3\text{O}_3 + 3\text{HIO}$ .

Acetate of lead is made by boiling litharge in acetic acid. It crystallizes in flat tables, containing 3 equivalents of water. It is commonly known as sugar of lead. 100 parts of water dissolve 59 parts of this salt at  $60^\circ$ . It is also soluble in



alcohol. It has an intensely sweet astringent taste; and in large doses it is poisonous.

*Subacetate of Lead.*—Formula,  $3 \text{ PbO}, \text{C}_4\text{H}_3\text{O}_3 + \text{HO}$ .

The salts of lead have a great tendency to form basic salts. By boiling the acetate with litharge, the subacetate is obtained; sometimes called *Goulard's Extract*. It is really the tribasic acetate. It is very soluble in water, so much so that it cannot be crystallized. When the solution is exposed, it absorbs carbonic acid from the air very rapidly; sometimes the mere addition of ordinary water precipitates a carbonate, by means of the carbonic acid it contains.

The salts of lead are isomorphous with those of lime.

*Carbonate of Lead.*—Formula,  $\text{PbO}, \text{Co}_2$ .

This may be prepared by the addition of carbonate of soda to the nitrate of lead. For commercial purposes, it is manufactured to an immense extent by a different process; it is called *ceruse*. It is a white powder, very heavy, insoluble in water, but soluble in nitric and acetic acid.

Carbonate of lead is made in the lead factories as follows:

Fine sheet lead is exposed in earthen pots to the fumes of acetic acid or vinegar, which is placed in the bottom of the pots; a heat of  $75^\circ$  is necessary to the process. Part of the acetic acid is decomposed, giving oxygen to the lead, forming the protoxide, which then unites with some undecomposed acid, forming the subacetate. This salt is then decomposed by carbonic acid escaping from manure, or exhausted tan, in which the pots are buried in successive layers. A carbonate of lead is thus formed, which varies in the amount of carbonic acid it contains. That the carbonic acid does not result from the decomposition of the acetic acid, is proved by the fact that 500 times more of carbonic acid is made than would result from the decomposition of the acetic acid present.

*Chloride of Lead.*—Formula,  $\text{PbCl}$ .

This is made by the addition of common salt to a solution

of the nitrate or acetate. It is white and insoluble, resembling very much the chloride of silver; but the latter becomes black by exposure, this does not.

The *Iodide and Bromide* are obtained in the same way. The former is beautifully yellow, the latter is white. Iodide of potassium will detect two millionths of its weight of lead.

*Tests.*—1. Potassa precipitates lead from its soluble salts, and the precipitate is soluble in excess of the precipitant.

2. The chloride is soluble in nitric acid.

3. Sulphuric and carbonic acids form insoluble salts.

4. The iodide of potassium forms a beautiful yellow precipitate with a soluble salt.

5. Chromate of potassa yields the beautiful yellow chromate of lead, which is much used in the arts.

6. Sulphuretted hydrogen precipitates the black sulphuret.

#### CERIUM.

Symbol,	Ce
Equivalent,	45.98
Infusible, except by the oxy-hydrogen blow-pipe.	

Cerium was discovered in Sweden, in a mineral called *cerite*. It was named after the planet Ceres. It has two oxides, viz., the pro and sesquioxide.

#### LANTANUM.

Symbol,	Ln
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This metal was discovered in the oxide of cerium, by Mosander; and it was called so because it has its properties hidden or masked. It has two oxides.

## DIDYMIUM.

Symbol, . . . . . Di

This metal is also found with cerium. It was discovered and named by Mosander, because it is a twin metal, or always associated with cerium.

## URANIUM.

Symbol	. . . . .	U
Equivalent,	. . . . .	60.
Specific gravity,	. . . . .	9.

This metal is got in *pitch blende*, in which it exists as an oxide. The sesquioxide is a beautiful yellow powder, used for colouring porcelain orange.

## CLASS V.

METALS PROPER, WHOSE OXIDES ARE ACIDS OR WEAK BASES.

## TIN.

Symbol,	. . . . .	St
Equivalent,	. . . . .	58.82
Specific gravity,	. . . . .	7.29
Melts at	. . . . .	442°

Tin was known to the ancients; it was obtained by them originally in Cornwall, and was used for the manufacture of bronze. It is generally found as the oxide, or, as it is called, *tin-stone*. The metal is obtained from the oxide by roasting,

and then heating with carbon. There are two varieties of ore, viz., vein, and stream ore, the names of which indicate their origin; the metal obtained from the latter source is the best. It is called stream tin.

Tin is the whitest of all the metals except silver; it fuses at  $442^{\circ}$ , and contracts on cooling. It is soft and inelastic, and when bent, emits a crackling noise. Heated to whiteness, it takes fire, and burns with a white flame, being converted into the bioxide.

Tin has a very slight affinity for oxygen, and remains unchanged in air or moisture; but when an acid is present, it becomes coated with a gray covering, which is the protoxide.

Tin is much used in the arts for coating iron, and in the manufacture of pewter.

#### COMPOUNDS OF TIN.

Protoxide, . .	SnO	58.82+8	= 66.82
Sesquioxide, . .	Sn <sub>2</sub> O <sub>3</sub>	117.64+24	=141.64
Bioxide, . .	SnO <sub>2</sub>	58.82+16	= 74.82
Protochloride, .	SnCl	58.82+35.41	= 94.23
Bichloride, . .	SnCl <sub>2</sub>	58.82+70.82	=129.64
Sulphurets.			

*Protoxide of Tin.*—Formula, SnO; equivalent, 66.82.

This oxide is obtained by the slow oxidation of tin in the air; it is basic.

*Sesquioxide of Tin.*—Formula, Sn<sub>2</sub>O<sub>3</sub>; equivalent, 141.64.

This is produced by the action of the hydrated sesquioxide of iron on the protochloride of tin; it is grayish.

*Bioxide of Tin.*—Formula, SnO<sub>2</sub>; equivalent, 74.82.

This is prepared by adding nitric acid to metallic tin; the acid is decomposed, yielding up 2 equivalents of oxygen to the tin, thus forming a bioxide, which remains as such, not uniting with the acid. It may also be got by precipitation

from a solution of the bichloride; obtained thus, it is a white hydrate, which is soluble in acids.

*Protochloride of Tin.*— $\text{SnCl}$ ; equivalent, 94.23.

Tin is acted on very powerfully by chlorine, and two chlorides may be formed as well as two oxides. The present salt is made by dissolving the metal in chlorohydric acid. It crystallizes in needles containing 3 equivalents of water. It may be got anhydrous by distilling tin and calomel together.

The protosalts of tin are remarkable for their tendency to enter into higher combinations, and they hence become very valuable reagents to the chemist.

A proto-compound will deoxidize any of the per compounds of the metals. Thus, ink is rendered colourless by having a protoxide or protochloride of tin presented to it; because the tin takes away oxygen from the ink, which is a tannate of the sesquioxide of iron, and it is converted into a tannate of the protoxide, which is colourless.

*Bichloride of Tin.*—Formula,  $\text{SnCl}_2$ ; equivalent, 129.64.

This is made by passing a stream of chlorine gas over metallic tin. A thick, heavy, whitish liquid, results, formerly called the *fuming liquor of Libavius*. It has such a powerful affinity for water, that it fumes on exposure to the air, from the absorption of watery vapour.

*Sulphurets of Tin.*—*Protosulphuret* is made by fusing tin with excess of sulphur, and heating the product.

*Bisulphuret*,  $\text{SnS}_2$ . This is made by passing sulphuretted hydrogen through the bichloride; but it is more readily formed by heating the bioxide with sulphur and the chloride of ammonium. This is commonly called *Mosaic gold*; it is used for the rubber of electrical machines.

These compounds of sulphur and tin are really sulphur acids, and they will unite with sulphur bases.

*Tests.*—1. The protosalts are tested by forming a beautiful

purple compound, called *purple of Cassius*, by adding them to the terchloride of gold (the purple of Cassius is used for colouring porcelain). They are also very readily tested by their decolorization of ink.

2. The per-compounds are tested by giving a yellow precipitate with sulphuretted hydrogen, and sulphuret of ammonium, the latter of which is soluble in excess of the precipitant.

#### ANTIMONY.

Symbol,	.	.	.	.	.	.	.	Sb
Equivalent;	.	.	.	.	.	.	.	129.04
Specific gravity,	.	.	.	.	.	.	.	6.80
Melts just below red heat.								

This metal was known to the ancients, and was called *stibium*. It was first minutely described by Basil Valentine, a monk of the fifteenth century.

It is found principally as the sulphuret in Germany, India, &c. This sulphuret, called crude ore, is washed and levigated; thus treated, it is called prepared antimony. When this is heated with iron, a sulphuret of iron is obtained, and the metal antimony is reduced.

It is a brittle, white metal, with considerable lustre; it is fluid at  $1000^{\circ}$ , and congeals in rhombohedrons. When melted and thrown on a surface, it attracts oxygen from the air, and undergoes a curious kind of combustion, forming no less than three compounds with oxygen.

An alloy of antimony and lead is used for making types, because it expands very much in cooling, and therefore takes a very sharp impression. The constituents of this alloy separately contract very much on cooling.



## COMPOUNDS OF ANTIMONY.

Teroxide, . . .	$\text{SbO}_3$	$129\cdot04 + 34 = 153\cdot04$
Antimonious Acid, .	$\text{SbO}_4$	$129\cdot04 + 32 = 161\cdot04$
Antimonic Acid, . .	$\text{SbO}_5$	$129\cdot04 + 40 = 169\cdot04$
Terchloride, . . .	$\text{SbCl}_3$	
Pentachloride, . . .	$\text{SbCl}_5$	
Tersulphuret, . . .	$\text{SbS}_3$	
Sulphantimonious Acid,	$\text{SbS}_4$	
Pentasulphuret, or Sulphan-		
timonic Acid, . . .	$\text{SbS}_5$	
Tartrate of Antimony and		
Potassa, . . . . .	$\text{SbO}_3, \text{KO}, \text{C}_8\text{H}_{10}\text{O}_4 + 2\text{HO}$ .	

The compounds of antimony will be described in connexion.

*Teroxide of Antimony.*—Formula,  $\text{SbO}_3$ ; equivalent, 153·04.

This is one of the products of combustion when antimony is melted and suddenly projected in the air; it forms a white cloud, which when condensed, assumes the form of beautiful white needles, which have been called the *Argentine flowers of antimony*. All the oxides of antimony are very feeble bases, but this is the most basic one; it therefore enters into all the salts of antimony, in which the latter acts the part of a base. But all the compounds of the antimony are acid, and unite with bases, not excepting the present one, which has been, therefore, called hypoantimonious acid.

This oxide has a corresponding chloride, sulphuret, &c. It may also be obtained by merely throwing the terchloride in water, and drying the precipitate which takes place. Got thus, it is of a pale buff powder.

*Terchloride of Antimony.*—Formula,  $\text{SbCl}_3$ .

This may be prepared by boiling sulphuret of antimony with chlorohydric acid, or by throwing powdered antimony in large excess in chlorine gas; combustion ensues, and the ter-

chloride is formed. It is a white crystalline mass, from which the air must be excluded; sometimes called *butter of antimony*.

So feeble is the basic property of the antimony in this compound that water displaces it; a white precipitate occurs on the mere addition of water, which precipitate is a mixture of the teroxide and terchloride; sometimes called the oxy-chloride.

*Tersulphuret of Antimony*.—Formula  $\text{SbS}_3$ .

This is found native. It is also obtained by passing sulphuretted hydrogen through a solution of tartar emetic, or any salt containing the teroxide. Found native, it is black, but that obtained in the laboratory is of an orange colour. Prepared by passing sulphuretted hydrogen through a salt, precipitation would not take place if a free alkali were present for the sulphur to unite with, because the tersulphuret of antimony would act as an acid and unite with the sulphuret of the alkaline metal thus formed, and the salt thus produced is soluble. It would be the *hypoantimonite of the sulphuret of potassium*, provided potassa were the alkali present. Hence the precipitate of tersulphuret is soluble in potassa.

*Antimonious Acid*.— $\text{SbO}_3$ ; equivalent, 161·04.

This is the ultimate product of the burning of antimony in the air. It is of no consequence.

*Sulphantimonious Acid*.—Formula,  $\text{SbS}_4$ .

This is formed by heating the last body with sulphur.

*Antimonic Acid*.—Formula,  $\text{SbO}_5$ ; equivalent, 160·04.

This is obtained by heating antimony with nitric acid, or still better, by heating it with nitrate of potassa. The nitric acid loses oxygen to the antimony, which then unites with the potassa, forming the antimoniate of potassa. (This is used as a test for soda). The potassa may then be removed by any acid, and then by heating the acid is rendered anhydrous. It has a yellow colour.

*Pentasulphuret of Antimony, or Sulphantimonic Acid.*—Formula,  $\text{SbS}_5$ .

This is prepared by heating the last with sulphur, or passing sulphuretted hydrogen through the solution of the antimoniate of potassa.

*Pentachloride of Antimony.*—Formula,  $\text{SbCl}_5$ .

This is made by burning antimony in excess of chlorine gas.

*Tartrate of Antimony and Potassa.*—Formula,  $\text{SbO}_3, \text{KO}, \text{C}_8\text{H}_{10}\text{O}_4 + 2\text{HO}$ .

This salt, commonly called tartar emetic, is made by boiling the teroxide of antimony with cream of tartar. It is not a double, but it is a bibasic salt; because tartaric acid is analogous to phosphoric (that is, polybasic), and unites with two bases. The bases in acid tartrate of potassa (cream of tartar), are potassa and water; but the latter being only a very feeble one, does not neutralize the acid, and the salt has therefore an acid taste and reaction. Now, when the teroxide of antimony is boiled with cream of tartar, it takes the place of the water, and there is formed the neutral bibasic salt, tartrate of antimony, and potassa. It crystallizes in octohedrons, holding two equivalents of water of crystallization. They are translucent, efflorescent, soluble in water, and emetic.

*Kermes' Mineral, and Golden Sulphuret of Antimony.*—These two compounds vary much in constitution; no two specimens being similar.

Kermes' mineral, is made by boiling the tersulphuret of commerce with potassa. The antimony is all dissolved, because a sulphuret of potassium is formed, which unites with the tersulphuret of antimony, acting as a sulphur acid, and the tersulphuret of the sulphuret of potassium is obtained in solution. There is also formed a teroxide of antimony, by the antimony which has yielded its sulphur to the potassa uniting with the oxygen of the potassa, and this then unites with some undecomposed potassa, forming an oxy-salt, which may

be called the hypoantimonite of potassa. These two salts are now held in the solution until it cools, when the water deposits part of the two acids. This precipitate when collected is of an orange colour; it is a teroxide along with a tersulphuret of antimony. Formula,  $\text{SbO}_3 + \text{SbS}_3$ .

*Golden Sulphuret.*—There still remains in solution a tersulphuret in combination with the sulphuret of potassium, and a teroxide in combination with potassa.  $\text{KS}, \text{SbS}_3 + \text{K}_2\text{O}, \text{SbO}_3$ . Now, if an acid be added to this solution, the potassa is removed, and the tersulphuret is precipitated in combination with the additional sulphur of the sulphuret of potassium, which has been decomposed by the acid. The teroxide is also thrown down. This compound is very nearly the same as the other, only the additional sulphur makes it much yellower.

*Tests.*—1. Sulphuretted hydrogen added to a soluble salt, gives the yellow sulphuret. By heating this with iron, the metal is obtained, which is distinguished from arsenic by not volatilizing, unless heated intensely.

In testing with sulphuretted hydrogen, it is necessary that no alkali be present, because in case there were, a soluble sulphur salt would be formed; hence, if there be any alkali, it must be removed by an acid.

2. Obtain the terchloride of antimony and add water; a white precipitate is obtained, which is the oxy-chloride.

#### ARSENIC.

Symbol, . . . . .	As
Equivalent, . . . . .	75.21
Specific gravity, . . . . .	5.88
Sublimes without fusing.	

Arsenic is found native in the crystalline form. It is also found associated with cobalt and iron. It is obtained from

these ores by roasting them in a reverberatory furnace; the arsenic is volatilized, combines with oxygen, and is deposited in white masses, called *white arsenic*; it is the teroxide.

The metal is got from this white oxide by heating it with black flux (which is obtained by charring cream of tartar, and is a mixture of carbon and carbonate of potassa). A bright red heat is sufficient for the process, which should be conducted with two crucibles, one inverted over the other. It is deposited in the upper one in octohedral crystals.

Arsenic has a brilliant steel-gray lustre, is crystalline, exceedingly brittle, and one of the most volatile of the metals. It sublimes at  $380^{\circ}$ , giving off an alliaceous odour; but if moisture be present, it will not sublime without being heated very highly. The result of the volatilization is the teroxide, if air or oxygen be present.

## COMPOUNDS OF ARSENIC.

Teroxide, or Arsenious Acid, . . . . .	$\text{AsO}_3$	$75 \cdot 21 + 24 = 99 \cdot 21$
Arsenic Acid, . . . . .	$\text{AsO}_5$	$75 \cdot 21 + 40 = 115 \cdot 21$
Terchloride, . . . . .	$\text{AsCl}_3$	
Pentachloride, . . . . .	$\text{AsCl}_5$	
Bisulphuret, . . . . .	$\text{AsS}_2$	
Tersulphuret, or Sulpharsenious Acid, . . . . .	$\text{AsS}_3$	
Pentasulphuret, or Sulpharsenic Acid, . . . . .	$\text{AsS}_5$	
Arsenietted Hydrogen, . . . . .	$\text{AsH}_3$	

Both the oxides of arsenic are acid bodies, and such feeble bases that water displaces them.

*Arsenious Acid*.—Formula,  $\text{AsO}_3$ ; equivalent, 99·21.

This is obtained (by volatilizing the metal) in white semi-translucent masses, which are volatile at  $380^{\circ}$ , and condense in beautiful crystals of adamantine lustre and perfect transparency; they are octohedrons. Eleven parts are soluble in one hundred parts of water at  $212^{\circ}$ , which, however, only retains three parts on cooling.

It forms salts of perfect solubility, called arsenites, which are isomorphous with the phosphites.

This compound of arsenic is generally called the *white oxide*; it is very poisonous.

*Arsenic Acid*.—Formula,  $\text{AsO}_5$ ; equivalent, 115.21.

This is prepared by heating the metal or arsenious acid with nitric acid; the latter is decomposed, yielding up its oxygen to form arsenic acid. This body is analogous to phosphoric acid, which it will displace in the phosphate of soda, and form the tribasic arseniate of soda. Formula,  $2\text{NaO}, \text{HO}, \text{AsO}_5 + 24\text{HO}$ . Arsenic acid is more soluble than arsenious acid.

*Suboxide of Arsenic*.—This is a mixture of the teroxide and the metal. It is a grayish or blackish powder, which is deposited on the surface of the metal when exposed; it is commonly called *flystone*.

*Terchloride of Arsenic*.—Formula,  $\text{AsCl}_3$ .

This is made by burning arsenic in chlorine gas, or by boiling arsenious acid in chlorohydric acid. If this terchloride be thrown in water, a precipitate is obtained by the water displacing the arsenic, which precipitate is a mixture of the teroxide and terchloride, called the oxy-chloride. In this respect it is analogous to the terchloride of antimony. By the addition of acid to the precipitate it is redissolved.

*Pentachloride of Arsenic*.—Formula,  $\text{AsCl}_5$ .

This is made by boiling arsenic acid with corrosive sublimate. It is always liquid.

*Bisulphuret of Arsenic*.—Formula,  $\text{AsS}_2$ .

This is prepared by heating arsenic and a minimum of sulphur out of contact with the air. It is a red, solid, glassy body, called *realgar*. It is a sulphur acid, and will unite with sulphur bases.

*Tersulphuret, or Sulpharsenious Acid*.—Formula,  $\text{AsS}_3$ .

This is obtained by passing sulphuretted hydrogen through



a solution of an arseniate in the presence of a free acid. It is a yellow body, called *orpiment*. If potassa be added to the precipitate, a resolution takes place, because a sulphuret of the alkaline metal is formed, by depriving the sulphuret of arsenic of part of its sulphur. This then unites with the tersulphuret of arsenic, forming a sulphur salt, which is the *sulpharsenite of the sulphuret of potassium*, it is soluble. Hence, when an alkali is present, no precipitate is produced, and when it is wished to determine the presence of arsenious acid by the sulphuretted hydrogen test, the solution must be acid, or an acid must be added to neutralize any alkali which may be present.

*Pentasulphuret of Arsenic, or Sulpharsenic Acid.*—Formula,  $\text{AsS}_5$ .

Made by passing sulphuretted hydrogen through a solution of an arseniate. It is a yellow precipitate.

*Tests.*—The tests for arsenic may be arranged under the heads of solid, liquid, and gaseous.

I. *Solid Tests.*—1. White crystalline powders in cases of poisoning are very suspicious; if these volatilize and condense in glassy crystals, or if placed in charcoal, thus reducing the metal and volatilizing it, and the garlicky vapours are perceived, then the suspicions are almost confirmed. But still this may be fallacious, because phosphorus and many other things have this odour.

2. Collect the white vapours and reduce them to the metallic state with charcoal or black flux, by heating them in a glass tube free from lead. The metal is deposited on the interior as a *tache*, giving the interior of the tube a mirror-like appearance. Moisture must be previously wiped out of the tube, because it elevates the temperature of volatilization. This test will detect one two-thousandth part of arsenic in any fluid.

II. *Liquid Tests.*—The solid test is not sufficient, for mer-

cury will give a similar metallic incrustation, and antimony will do the same, provided the heat be intense enough.

1. Pass sulphuretted hydrogen through the suspected liquid, and a yellow precipitate is obtained; but the sulphurets of tin, cadmium, &c., are also yellow. It is distinguished from these by adding potassa, which dissolves the sulphuret of arsenic, but not the others (for reasons already shown when treating of the tersulphuret of arsenic).

If the sulphuret of arsenic is now taken and heated with black flux, and the metallic tache and alliaceous odour are obtained, and besides, the vapours condense in glassy crystals, then it is almost rendered certain that arsenic is present.

2. Add the earths to the solution of arsenious acid, and a white precipitate is obtained; but this is not delicate.

3. Add to the solution a soluble salt of copper, as the sulphate, and along with it ammonia, or any alkali which will remove the sulphuric acid, and form with it a soluble salt, and a precipitate of the arsenite of copper will take place. The best preparation for this is *Fowler's Solution* (arsenite of potassa); double decomposition takes place; thus by symbols,  $\text{KO}, \text{AsO}_3$ , added to  $\text{CuO}, \text{SO}_3$ , gives  $\text{KO}, \text{SO}_3$ , and  $\text{CuO}, \text{AsO}_3$ . This precipitate is grass-green; it is called *Scheele's Green*.

4. Add nitrate of silver to the solution of arsenious acid, and no result will take place; but by adding ammonia, to neutralize the nitric acid, an arsenite of silver is obtained, which is of a beautiful *canary-yellow* colour. The best method for performing this test is to add ammonia to a solution of nitrate of silver; a precipitate is first obtained, which is redissolved by excess of ammonia, and the solution thus obtained added to the arsenious acid solution immediately gives the precipitate.

This precipitate resembles very much the tribasic phosphate of silver (got by adding the tribasic phosphate of soda

to the nitrate of silver); but this is exceedingly soluble in ammonia, while the other is not. Hence ammonia added to any liquid supposed to contain arsenious acid, will insure an arsenite, and prevent the formation of a phosphate as a precipitate.

The arsenite of potassa may be successfully used to form this test. It is much more delicate than the copper test.

To insure the success of the copper and silver tests, the solutions we use must be colourless; and as in cases of poisoning, the contents of the stomach and bowels are always mixed with organic matters, it becomes necessary to do something more.

A stream of sulphuretted hydrogen will give the yellow sulphuret of arsenic when an acid is present, and this result will take place, no matter what organic bodies are mixed with it. This sulphuret we distinguish by being soluble in excess of potassa. With this a colourless solution may be got for the copper and silver tests.

We can also remove the organic matter by other means. Take the stomach and bowels of a person poisoned: add water to the contents, &c., to dissolve out the soluble ingredients, taking care that the water is not hot enough to dissolve any arsenic; allow this to stand a little while, then pour the water off. Now add a mixture of one part of nitric and two parts of sulphuric acid to it, and heat the whole gently, but not sufficiently to volatilize the arsenic; the whole mass is soon charred. This is then washed, and all the organic matter is thus got rid of, and we then obtain a colourless solution, which we can test.

III. *Gaseous Test*.—The principle of this test, which is called Marsh's, is to evolve hydrogen gas by the action of sulphuric acid on metallic zinc (being careful that the latter contains no arsenic), in contact with the suspected solution.

The process is as follows: Add the suspected liquid to a self-generating reservoir, which has attached a glass tube for burning a jet of hydrogen. As the hydrogen is being evolved in a nascent condition, it unites with the arsenic, forming arseniетted hydrogen. Burn a jet of it, and hold a piece of dry white porcelain down low on the flame: arsenic will be deposited on the plate as a metallic tache; or if the plate be held farther from the flame, the arsenic is burned, and forms arsenious acid, which is deposited in white crystals. As the first jet of arseniетted hydrogen may contain all the arsenic and escape, a glass tube has been added to this apparatus, for the purpose of preventing this. The tube is heated sufficiently high in one portion to seize the arseniетted hydrogen and volatilize it as it passes over the heated portion, and the arsenic is deposited beyond the greatest point of heat, in the metallic state, because there is no oxygen in the tube to oxidize it. The only other metal which would be deposited is antimony, but as this requires a great deal higher heat to volatilize it, it would be deposited, if at all, at the point of greatest heat.

#### CHROMIUM.

Symbol, . . . . .	Cr
Equivalent, . . . . .	28.14
Specific gravity, . . . . .	5.90
Fusible by oxy-hydrogen blowpipe.	

Chromium was found originally in red lead ore in Siberia. It is also found in Maryland and Pennsylvania in what is called chromiferous iron ore. The last mineral contains chromium in the form of a sesquioxide combined with iron. The metal is obtained from this. It resembles steel, is hard, grayish-white and brittle. It is isomorphous with iron and manganese.

## COMPOUNDS OF CHROMIUM.

Sesquioxide, . . .	$\text{Cr}_2\text{O}_3$	$56 \cdot 28 + 24 = 80 \cdot 28$
Chromic Acid, . . .	$\text{CrO}_3$	$28 \cdot 14 + 24 = 52 \cdot 14$
Sesquichloride, . . .	$\text{Cr}_2\text{Cl}_3$	
Sulphate of Sesquioxide,	$\text{Cr}_2\text{O}_3, 3\text{SO}_3$	
Chromate of Potassa,	$\text{KO}, \text{CrO}_3$	
Bichromate of Potassa,	$\text{KO}, 2\text{CrO}_3$	

*Sesquioxide of Chromium.*—Formula,  $\text{Cr}_2\text{O}_3$ ; equivalent, 80·28.

This is a green body, prepared by heating the metal in the air. It is basic, and forms salts isomorphous with the sesquisalts of iron; it also enters into some double salts, as in *chrome alum*, in which it substitutes alumina, forming the sulphate of chromium and potassa; formula,  $\text{KO}, \text{SO}_3 + \text{Cr}_2\text{O}_3, 3\text{SO}_3 + 24\text{HO}$ . The sesquioxide may be obtained from this by the addition of an alkali, in the form of a green hydrate, remarkable for its extreme bulkiness; this, when dried, dwindles away as it were by magic, on account of the great quantity of water it holds.

*Chromic Acid.*—Formula,  $\text{CrO}_3$ ; equivalent, 52·14.

This is prepared by adding sulphuric acid in excess to a solution of the bichromate of potassa; all the potassa is removed, and a magnificent red solution remains, which yields beautifully red crystals of chromic acid. It is soluble in water.

Chromic acid is one of the best oxidizing bodies the chemist possesses; and is, therefore, very much used in organic analyses. There is not a single organic body that is not decomposed by chromic acid yielding up its oxygen to it, forming carbonic acid with its carbon, water with its hydrogen, and cyanic acid with its nitrogen. Alcohol is set on fire by merely throwing chromic acid into it.

*Sesquichloride of Chromium.*—Formula,  $\text{Cr}_2\text{Cl}_3$ .



This is made by boiling chromium in chlorohydric acid. It is also made by boiling the sesquioxide in the same acid. It is soluble, and its solution is green.

*Chromate of Potassa.*—Formula,  $\text{KOCrO}_3$ .

This is obtained by powdering chrome ore, which contains the sesquioxide, and heating it in a reverberatory furnace with nitrate of potassa; this imparts oxygen to the sesquioxide, and converts it into chromic acid, which then unites with the potassa, forming chromate of potassa. The whole mass is then taken from the furnace and lixiviated; a yellow solution is obtained, from which the chromate of potassa crystallizes out precisely like the sulphate of potassa, with which it is isomorphous. It is a yellow, soluble salt, much used for dyeing, on account of its immense colouring power.

*Bichromate of Potassa.*—Formula,  $\text{K}_2\text{O}, 2\text{CrO}_3$ .

This is made by adding sulphuric acid to the chromate of potassa in solution; half the potassa is removed. It is a red salt, soluble in ten parts of water.

*Tests.*—Chromium is known by the many-coloured compounds it forms, and from which it derives its name, from the Greek  $\chiρῶμα$ , colour.

For forming these, chromate of potash is used, and a soluble salt of the precipitant.

With lead, we have a yellow precipitate; with silver, red; with baryta, yellow; mercury, red, &c.

#### VANADIUM.

Symbol,	.	.	.	.	.	.	.	.	V
Equivalent,	.	.	.	.	.	.	.	.	68.55

This metal was discovered in Mexico, in an ore combined with lead. It resembles chromium very much. It forms three distinct compounds with oxygen, viz.:



Protoxide,	.	.	.	VO
Bioxide,	.	.	.	VO <sub>2</sub>
Vanadic acid,	.	.	.	VO <sub>3</sub>

The *protoxide* does not form salts.

The *bioxide* forms a series of blue salts.

*Vanadic acid* is red ; it unites with bases, forming a series of red and yellow salts.

## MOLYBDENUM.

Symbol,	.	.	.	.	Mo
Equivalent,	.	.	.	.	47.88
Specific gravity,	.	.	.	.	8.6

This metal was first obtained from the native sulphuret, a mineral very much resembling graphite. It is white, brittle, and very infusible.

It forms three oxides, viz. :

Protoxide,	.	.	.	MoO
Binoxide,	.	.	.	MoO <sub>2</sub>
Molybdic acid,	.	.	.	MoO <sub>3</sub>

## TUNGSTEN.

Symbol,	.	.	.	.	W
Equivalent,	.	.	.	.	94.64

Tungsten is got from *wolfran*, or heavy stone. It is white, hard, brittle, and very infusible. It forms two oxides, viz. :

Binoxide,	.	.	.	WO <sub>2</sub>
Tungstic acid,	.	.	.	WO <sub>3</sub>

## COLUMBIUM.

Symbol,	.	.	.	.	T
Equivalent,	.	.	.	.	184.59.

This is found in Massachusetts, in the mineral *columbite*, which is a columbite of lime.

It is a gray metal, forming two oxides, viz. :

Binoxide,	.	.	.	TO <sub>2</sub>
Columbic acid,	.	.	.	TO <sub>3</sub>

#### TELLURIUM.

Symbol,	.	.	.	.	.	Te
Equivalent,	.	.	.	.	.	64.14

This is a very rare metal, established by Klaproth.

It has an oxide, TeO, and an acid, TeO<sub>3</sub>.

Tellurium is one of the amphigen bodies.

#### TITANIUM.

Symbol,	.	.	.	.	.	Ti
Equivalent,	.	.	.	.	.	24.29

This is got in titanite, and sometimes at the bottom of iron furnaces. It is a hard, red, and infusible metal, except by the oxy-hydrogen blowpipe.

It has a Protoxide, TiO, and Titanic acid, TiO<sub>3</sub>.

### CLASS VI.

#### METALS WHOSE OXIDES ARE REDUCIBLE BY HEAT.

##### MERCURY.

Symbol,	.	.	.	.	.	Hg
Equivalent,	.	.	.	.	.	202
Melts at	.	.	.	.	.	—39°
Specific gravity,	.	.	.	.	.	13.57

Mercury was known to the ancients. In Spain it was found almost pure in the metallic state. It was supposed to be living silver, and hence the name. It is also found as a sulphuret, called *cinnabar*, in Spain, California, &c. It is obtained from the latter, by roasting, and condensing the vapours. Mercury has a steel-like lustre, great fluidity, and mobility, and when pure, it should not stain the whitest paper, neither should it tarnish by exposure. It boils at  $662^{\circ}$ , yielding a colourless vapour. The mercury of commerce is always impure; it is purified by distillation at  $700^{\circ}$ , and the vapours received in water.

Mercury, under ordinary circumstances, will not oxidize by exposure, but if it is boiled for a long time in contact with air, it unites with oxygen, and forms the bioxide; this is called *red precipitate per se*. The process is conducted in a flask with a very long tube or neck, so that when the vapours reach its upper extremity, they are cooled and fall; the apparatus is called *Boyle's hell*.

The equivalent of mercury is taken at 202, because that is the lowest proportion in which it will unite with 1 equivalent of oxygen, viz.,  $202+8$ , forming the protoxide; if 101 were the equivalent, this would be the sub or dioxide. Nitric acid is the proper solvent for mercury.

The alloys of mercury are called amalgams; these are all more or less soft, and most of them are definite.

## COMPOUNDS OF MERCURY.

Protoxide, . . .	HgO	202+8	=210
Binoxide, . . .	HgO <sub>2</sub>	202+16	=218
Chloride, . . .	HgCl	202+35.41	=237.41
Bichloride, . . .	HgCl <sub>2</sub>	202+70.82	=272.82
Bromide, . . .	HgBr	&c.	

Iodide, . . .	HgI
Biniodide, . . .	HgI <sub>2</sub>
Sulphuret, . . .	HgS
Bisulphuret, . . .	HgS <sub>2</sub>
Cyanide, . . .	HgCy <sub>2</sub>
Protosulphate, . . .	HgOSO <sub>3</sub>
Bisulphate, . . .	HgO <sub>2</sub> , 2SO <sub>3</sub>
Basic sulphate, . . .	3HgO <sub>2</sub> , 2SO <sub>3</sub> Turpeth mineral.
Protonitrate, . . .	HgONO <sub>3</sub> +2HO
Basic nitrate, . . .	2HgONO <sub>3</sub> +HO
Pernitrate, . . .	HgO <sub>3</sub> , 2NO <sub>3</sub>
Basic pernitrate, . . .	2HgO <sub>3</sub> , NO <sub>3</sub>
Chloramide, &c., &c.	

*Protoxide of Mercury.*—Formula, HgO; equivalent, 210.

The protoxide is made by adding soda or potassa to the protonitrate, or any protosalt which is soluble. Lime answers this purpose very well; decomposition results, and the hydrated protoxide is precipitated; it is grayish-black. This precipitate may be got by rubbing an alkali with calomel.

*Binoxide of Mercury.*—Formula, HgO<sub>2</sub>; equivalent, 218.

This is prepared by using Boyle's apparatus, already described, or by adding an alkali to a solution of a persalt, as the pernitrate. The hydrated bioxide is precipitated. This is yellowish, but by heating, the water is driven off, and it becomes red; it is called red precipitate.

*Protonitrate of Mercury.*—Formula, HgO, NO<sub>3</sub>+2HO.

As all the compounds of mercury may be obtained from the nitrates, it is well to commence with them.

Nitric acid is the proper solvent for mercury; and when the latter is added to the dilute acid, in the cold, a nitrate of the protoxide is obtained. The mercury is oxidized at the expense of the nitric acid.

It forms colourless crystals soluble in water.

*Basic Nitrate.*—Formula, 2HgO, NO<sub>3</sub>+HO.

This is got by having the mercury in large excess over the nitric acid.

*Pernitrate of Mercury.*—Formula,  $\text{HgO}_2, 2\text{NO}_5$ .

This is made by adding an excess of strong hot nitric acid to mercury; the nitrate of the bioxide is formed. It is a solid white body.

*Basic Pernitrate.*—Formula,  $2\text{HgO}_2, \text{NO}_5$ .

This is prepared by throwing the pernitrate into water; decomposition results, giving a supernitrate and the basic pernitrate, which is precipitated.

*Sulphate of Protoxide of Mercury.*—Formula,  $\text{HgO}, \text{SO}_3$ .

This is made by adding sulphuric acid to the nitrate of the protoxide in solution; the one acid displaces the other, and the sulphate being insoluble is precipitated. It is white and crystalline.

*Bisulphate of Bioxide of Mercury.*—Formula,  $\text{HgO}_2, 2\text{SO}_3$ .

This may be got by adding sulphuric acid to the pernitrate, but it is generally made by boiling sulphuric acid with metallic mercury. Part of the acid is decomposed, its oxygen going to the mercury to form a bioxide, which then unites with some undecomposed acid. Sulphurous acid gas is given off.

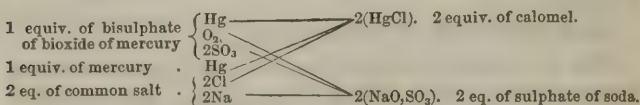
It is white, amorphous, and when thrown into water it is decomposed into super and subsulphate. The latter is precipitated. It is called *Turpeth mineral*. Really it is the *basic sulphate*. Formula,  $3\text{HgO}_2, 2\text{SO}_3$ .

*Protochloride of Mercury.*—*Calomel*.  $\text{HgCl}$ .

This may be made by passing the vapour of mercury into chlorine gas; also by boiling the protoxide in chlorohydric acid, double decomposition results, giving water and the protochloride. The calomel of medicine is obtained, however, by a different process.

A sulphate of the bioxide is first obtained by boiling mercury with three parts of sulphuric acid; an additional equivalent of mercury is then added, and the whole intimately mixed with

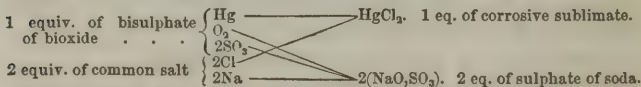
chloride of sodium. Heat is applied and the mass sublimed. Reaction takes place at a red heat; the oxygen of the mercury unites with the sodium, forming sulphate of soda, while the chlorine of the sodium unites with the mercury, forming the protochloride.



It is deposited in the upper part of the apparatus in beautiful white crystals. The powder has a creamy hue. It is very insoluble in water, requiring 30,000 times its weight to dissolve it. Calomel may also be obtained by adding a soluble chloride to the protonitrate in solution. The salt obtained by sublimation always contains some bichloride. From this it is purified by merely washing it with water.

*Bichloride of Mercury.*—Formula,  $\text{HgCl}_2$ .

The bichloride, commonly called *corrosive sublimate*, is made by subliming the bisulphate of the bioxide with two parts of common salt; double decomposition results, giving two equivalents of sulphate of soda, and one equivalent of the bichloride of mercury.



This condenses in crystals more massive and less brilliant than those of calomel. They are soluble in water, requiring 16 parts cold, and 3 parts boiling water. This salt is also soluble in alcohol and ether. It is very poisonous. Its antidote is albumen or bisulphuret of iron; the latter is said to convert the mercury into vermilion (bisulphuret), which is insoluble and inert.

Bichloride of mercury combines with a great many other



chlorides, and forms a series of double salts. Such a salt is the *sal alembroth*. It is prepared by adding the chloride of ammonium in excess to the bichloride of mercury. Formula,  $2\text{Cl}_2\text{Hg} + \text{Cl}, \text{NH}_4$ ; that is, two equivalents of the bichloride of mercury in combination with one of chloride of ammonium. It is white and crystallizable.

*Protiodide of Mercury*.—Formula,  $\text{HgI}$ .

This is made by triturating mercury, iodine, and alcohol together; the mercury must be in excess. It is a green salt. It may also be made by adding iodide of potassium to the protonitrate.

*Biniiodide of Mercury*.—Formula,  $\text{HgI}_2$ .

This is made by triturating mercury with an excess of iodine, or by the addition of iodide of potassium to the pernitrate. It is a beautiful red salt. If it be heated so as not to volatilize it; its molecular condition is changed, and it becomes yellow; but by rubbing it, it again becomes red.

*Bromides*.—These are made by adding bromide of potassium to the proto and persalts of mercury; they are both white.

*Cyanide of Mercury*.—Formula,  $\text{HgCy}_2$ .

This may be made by boiling cyanhydric acid with the red oxide (bioxide), or by heating the ferrocyanide of iron (Prussian blue), with the bioxide of mercury. The cyanogen in the latter case displaces the oxygen, forming the bicianide; while the oxygen unites with the iron, forming the sesquioxide, which is precipitated. The bicianide of mercury is got from its solution in quadrangular crystals. This compound is usually resorted to for obtaining cyanogen gas; which it gives off by being heated to  $662^\circ$ , at which point the salt is decomposed, the mercury volatilizing along with the cyanogen. This cyanide will form double salts.

*Sulphurets of Mercury*.—The *bisulphuret*,  $\text{HgS}_2$ , exists

native in the Hartz, in Peru, and very abundantly in Spain. It is called *native cinnabar*; some metallic mercury also exists in the compound. It is made artificially by passing sulphuretted hydrogen through a solution of corrosive sublimate. The precipitate thus obtained is black, and not red, owing to its being a hydrate. But by drying and subliming beautiful red crystals are obtained, which, when powdered, are called vermilion. The best is made in China.

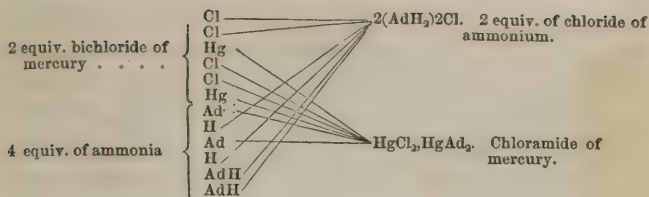
The *protosulphuret*,  $\text{HgS}$ , is made by passing sulphuretted hydrogen through a solution of the protonitrate; also by triturating mercury and sulphur together. It is black; and was originally called *Ethiops mineral*.

*Chloramide of Mercury*.—Formula,  $\text{HgAd}_2$ ,  $\text{HgCl}_2$ .

When ammonia is added to a solution of the bichloride of mercury, a white precipitate is thrown down, called *ammoniated mercury*. It is really, however, the biamide in combination with the bichloride of mercury.

Amidogen is a compound of one equivalent of nitrogen combined with two equivalents of hydrogen; that is, it is ammonia deprived of one equivalent of hydrogen. Formula,  $\text{NH}_2$ , represented by Ad. This amidogen is also a compound radical, acting the part of an element, and only existing in combination.

Now, when ammonia, which may be considered as a compound of one equivalent of amidogen and one of hydrogen, is added to the bichloride of mercury, part of the ammonia is decomposed, and also a part of the bichloride; the chlorine takes hydrogen from the ammonia, converting it into amidogen, which then unites with the mercury which has been freed, forming thus the biamide, which again unites with some undecomposed bichloride, and forms a double salt, which is precipitated. Chloride of ammonium is also formed, and remains in solution.



*Tests.*—1. Lime water and all the alkalies except ammonia give a precipitate of the black protoxide with the protosalts. With the persalts they give a yellow precipitate, which becomes red.

2. The protochloride of tin, when added to a protosalt, and heated, gives a black precipitate, which, when collected and heated, is found to be metallic mercury.

3. Iodide of potassium gives a green precipitate, (iodide of mercury) with a protosalt, and a red precipitate (biniodide of mercury) with a persalt.

4. Sulphuretted hydrogen gives black precipitates with both proto and per salts.

5. An elegant little test for a soluble salt of mercury, is to place a drop of its solution on a bright piece of gold, then place the point of a penknife in the drop, and a white spot will be observed immediately on the gold. This is due to the little galvanic circle formed by the fluid and two metals, producing a decomposition of the fluid, causing the mercury to be evolved at the gold, in a metallic state, and forming an amalgam, which is white; while the other element or acid is evolved at the iron.

## SILVER.

Symbol, . . . . .	Ag
Equivalent, . . . . .	108.12
Specific gravity, . . . . .	10.50
Melts at . . . . .	1873°

Silver is obtained in Siberia in the metallic state, in the form of threads and scales. It is most abundant, however, in the form of chlorides and sulphurets; these ores are found in different parts of the world, as Germany, Russia, North and South America, &c.

The metal is obtained by two processes, viz. : by cupellation and amalgamation. The first process is used for argentiferous galenas, which are sulphurets of lead and silver. The ore is crushed and roasted; the mass is then melted, the lead is converted into a protoxide, which melts and runs away. When the lead has been thus removed, the mass, which still contains some lead, is transferred to a cupel and heated, the last of the lead is oxidized and sinks into the cupel, leaving a globule of silver, very pure and remarkable for its brilliancy.

The cupel is a dish made of bone earth, so porous as to allow melted lead to sink in it, yet at the same time so infusible as to bear an intense heat.

If the silver contain gold, it is got rid of by nitric acid, which will dissolve the silver but not the gold; if it contain copper, the solution will be blue.

The process by amalgamation is to grind the ores, then add mercury, and agitate the whole mass for some time, when an amalgam of mercury and silver will be formed. The mercury is then got rid of by subliming.

Silver is one of the whitest and most brilliant of the metals; when pure, it is very soft and malleable, and is one of the very best conductors of heat and electricity. It does not

oxidize by exposure to air or moisture; when fused, however, it absorbs many times its volume of oxygen, which it again gives out on solidifying. Silver is isomorphous with the alkaline metals proper.

## COMPOUNDS OF SILVER.

Suboxide . .	$\text{Ag}_2\text{O}$	. .	$216+8=224$
Protoxide . .	$\text{AgO}$	. .	$108+8=116$
Nitrate . .	$\text{AgO}, \text{NO}_3$	. .	&c.
Sulphate . .	$\text{AgO}, \text{SO}_4$		
Chloride . .	$\text{AgCl}$		
Sulphuret . .	$\text{AgS}$		

*Suboxide of Silver.*—Formula,  $\text{Ag}_2\text{O}$ . Equivalent, 224.

This is prepared by forming a citrate of silver, and then exposing it to heat in a stream of hydrogen gas; it thus loses oxygen, and what remains is free citric acid, and citrate of suboxide of silver. The latter is then precipitated by an alkali. It is a black powder.

*Protoxide of Silver.*—Formula,  $\text{AgO}$ . Equivalent, 116.

This is prepared by adding an alkali to the nitrate; it is a copious brown precipitate, which, when dried, is nearly black. It is basic, and forms colourless salts. It is very soluble in ammonia.

*Nitrate of Silver.*—Formula,  $\text{AgO}, \text{NO}_3$ .

This is obtained by the addition of nitric acid to metallic silver, of which it is the proper solvent. The solution by evaporation yields colourless crystals, which, when fused and cast into moulds, constitute *lunar caustic*. The nitrate is very soluble.

By exposure to light, especially in the presence of organic matter, it becomes black.

*Sulphate of Silver.*—Formula,  $\text{AgO}, \text{SO}_3$ .

This may be got by the addition of a sulphate of an alkali to a solution of the nitrate.

*Chloride of Silver.*—Formula,  $\text{AgCl}$ .

This is got by adding common salt to the nitrate in solution. The precipitate is white, flocculent, and collects in tufts, which sink. It gets dark by exposure to light. When heated it melts, and on cooling it becomes a crystalline mass, which cuts like horn. It is found native thus, and is called *horn-silver*. It is freely soluble in ammonia, but very insoluble in water.

The *bromide* resembles this very much, but it is not so freely soluble in ammonia.

The *iodide* is got as a pale canary yellow.

*Sulphate of Silver*.—Formula,  $\text{AgS}$ .

This may be made by passing a stream of sulphuretted hydrogen through any soluble salt of silver. It also exists native in galenas.

*Fulminating Silver*.—This is made by dissolving the precipitated oxide in ammonia. This explodes on the slightest touch. The reason is, that the silver has a very feeble affinity for oxygen, while the hydrogen of the ammonia has a very powerful affinity for it, hence the slightest disturbing cause is sufficient to make the hydrogen and oxygen unite, which they do with light and heat, generating water; nitrogen is also set free, and metallic silver is precipitated.

#### METHOD OF SEPARATING SILVER FROM ITS COMPOUNDS.

Silver is separated from any of its compounds by chlorine. In mints, a solution of the nitrate is first formed, and then a solution of known strength of chloride of sodium is added; all the silver is precipitated. This precipitated chloride is then mixed with granulated zinc, and dilute sulphuric acid is added, hydrogen gas is evolved, which being in its nascent state, unites to the chlorine of the chloride and forms chlorohydric acid, sulphate of zinc remains in solution, and perfectly pure silver is precipitated as a greenish-black powder, which when melted, is metallic silver.



Silver is also separated from its compounds in solution by copper or mercury. The latter forms the *Arbor Dianæ*, by precipitating metallic silver from its solution.

*Tests.*—1. Add chloride of sodium to a soluble salt, and a white flocculent precipitate is obtained, which becomes dark by exposure to light. This precipitate is the protochloride.

## GOLD.

Symbol,	.	.	.	.	.	.	.	Au
Equivalent,	.	.	.	.	.	.	.	99.44
Specific gravity,	.	.	.	.	.	.	.	19.5
Melts at	.	.	.	.	.	.	.	2016°

Gold is not found associated with the more common metallic bodies. It is distributed all over the earth, but always associated with the same kind of rock, which is quartz. It is always in the metallic state, but sometimes it is alloyed with silver. From silver it is separated by a process called *quartation*; if the gold contain but a small percentage of silver, the latter remains intact to the action of acids; but if the silver be in excess, the whole may be removed by nitric acid. Hence three parts of silver are added to the gold which contains the silver, to be separated, and the gold thus constitutes only one-fourth of the mass; nitric acid is added, and the whole of the silver is thus separated.

Gold is got from *auriferous quartz*, by stamping it to powder, and then shaking with water and mercury; an amalgam is thus obtained, from which the gold is separated by sublimation.

Gold is the only metal which is yellow. It is the most malleable of the metals. It is not affected by air or moisture, or by any of the ordinary acids. Its proper solvent is chlorine.

## COMPOUNDS OF GOLD.

Protoxide, . .	AuO	99·44+ 8	=107·44
Teroxide, . .	AuO <sub>3</sub>	99·44+ 24	=123·44
Protochloride, .	AuCl	99·44+ 35·41	=134·85
Terchloride, . .	AuCl <sub>3</sub>	99·44+106·23	=215·67

*Protoxide of Gold.*—Formula, AuO ; equivalent, 107·44.

The protoxide is made by adding potassa to the protochloride. It is a green powder, which is rapidly decomposed into its constituents.

*Peroxide of Gold.*—Formula, AuO<sub>3</sub>; equivalent, 123·44.

This is made by concentrating the terchloride without crystallizing it, and then adding potassa. The brown teroxide is precipitated. This is freely soluble in the alkalies; and when digested in ammonia, forms fulminating gold. It is sometimes called *auric acid*.

*Protochloride of Gold.*—Formula, AuCl; equivalent, 134·85.

This is got by heating the terchloride; part of the chlorine is driven off, leaving the protochloride in the form of a yellowish-white mass, insoluble in water.

*Terchloride of Gold.*—Formula, AuCl<sub>3</sub>; equivalent, 215·67. The proper solvent of gold is chlorine, and this is very readily developed by mixing nitric and hydrochloric acids in the proportion of one of the former to two of the latter; the mixture is called *aqua regia*.

Gold is dissolved very readily in this acid, giving a rich yellow solution, which by evaporation yields red crystals.

Phosphorus, carbon, and many other bodies dipped in this solution become gilded; ribands dipped in it and then submitted to a stream of hydrogen gas, become coated with gold.

*Tests.*—The terchloride is decomposed by the protosalts of iron and tin, both having a tendency to pass into higher states of oxidation. The iron salt precipitates the gold in

the form of a brownish powder; but a purple precipitate is obtained, called *purple of Cassius*, when the protochloride of tin is added to the terchloride of gold.

## PLATINUM.

Symbol, . . . . .	Pt
Equivalent, . . . . .	98.68
Specific gravity, . . . . .	21.5
Melts only before the oxy-hydrogen blowpipe.	

Platinum is always found associated with other metallic bodies; these are generally palladium, rhodium, iridium, and osmium. This alloy is found in Peru, Saxony, and especially in the Ural Mountains. It occurs in flattened water-worn grains. The metal is obtained from its alloys as follows: Aqua regia is added to the native alloy, and bichlorates of platinum, palladium, and rhodium are obtained, while iridium, osmium, and ruthenium remain untouched. The bichloride of platinum is in the largest excess in the solution, because it constitutes 80 per cent. of the alloy. It is separated from the other two compounds by the property it has of forming double salts with alkalies. Chloride of potassium is therefore added, and a yellow precipitate is obtained, which is the double salt, bichloride of platinum plus the chloride of potassium. If the chloride of ammonium be substituted, a similar double salt is obtained, from which the metal platinum can be obtained, by exposing it to a white heat, which drives off the ammonia and chlorine. The metal is thus obtained in a spongy condition, called *spongy platinum* and *platinum black*, which, if heated and hammered, constitutes the proper metal.

Platinum is white, very heavy, exceedingly malleable and ductile, and capable of being welded. It undergoes no change

by air or moisture, and may be submitted to the most intense heat of a smith's forge without fusion or oxidation. Its only solvent, like gold, is chlorine. Its great use to the chemist is for crucibles, without which organic chemistry would be but little known.

Spongy platinum possesses the remarkable property of firing hydrogen and oxygen. This has been called katalytic action; but it is said that it is owing to the immense condensing power of the mass, and the hydrogen and oxygen are thus brought atom to atom, or within the spheres of their molecular attractions, and then unite.

#### COMPOUNDS OF PLATINUM.

Protoxide, . . . . .	PtO	98·68 + 8 = 106·68
Peroxide, . . . . .	PtO <sub>2</sub>	98·68 + 16 = 114·68
Protochloride, . . . . .	PtCl	
Bichloride, . . . . .	PtCl <sub>2</sub>	

*Protoxide of Platinum.*—Formula, PtO; equivalent, 106·68.

This is prepared by adding potassa to the protochloride. It is a black powder, soluble in excess of the alkali.

*Bioxide of Platinum.*—Formula, PtO<sub>2</sub>; equivalent, 114·68.

This is a brown powder, got by the addition of an alkali to the bichloride.

*Protochloride of Platinum.*—Formula, PtCl.

This is obtained by heating the bichloride to 400°. It is a greenish powder, insoluble in water. It forms double salts.

*Bichloride of Platinum.*—Formula, PtCl<sub>2</sub>.

This is got by means already stated. It forms double salts, and by these means serves to test potassa from soda, because the double salt of the latter is soluble, while the former is not. The formula for the double chloride of platinum and potassium is, PtCl<sub>2</sub> + KCl; for the soda salt, PtCl<sub>2</sub> + NaCl;

and for the ammonia salt,  $\text{PtCl}_2 + \text{NH}_4\text{Cl}$ . It is from the last salt that the metal is obtained by heat.

*Tests.*—Platinum is tested by its bichloride forming yellow double salts with the chlorides of the alkalies.

## PALLADIUM.

Symbol, . . . . .	Pd
Equivalent, . . . . .	33.77
Specific gravity, . . . . .	11.8
Melts at the highest heat of a smith's forge.	

This metal is always found associated with platinum. It forms iodides, which serve to distinguish it from that metal. In the process for obtaining platinum, we have seen palladium obtained in the form of a bichloride; now by adding iodide of potassium to this, a very dark brown precipitate is obtained, which is the iodide of palladium. By heating this the iodine is driven off and the metal left.

Palladium resembles platinum very much, but it oxidizes more readily, and is more fusible. It is soluble in nitric acid, but its best solvent is *aqua regia*. It forms salts like those of platinum.

## RHODIUM.

Symbol, . . . . .	R
Equivalent, . . . . .	52.11
Specific gravity, . . . . .	11.
Fusible by oxy-hydrogen blowpipe.	

The bichloride of rhodium is all that is left in solution after the platinum and palladium have been removed. From this rhodium is got, by forming the double salt, bichloride of rhodium and chloride of ammonium,  $\text{RCl}_2 + \text{NH}_4\text{Cl}$ , and then heating it. The spongy mass is then heated and hammered.

Rhodium and its compounds resemble platinum; but no

acid or combination of acids will touch it unless it be in the state of alloy, in which state aqua regia dissolves it. Its salts resemble those of platinum.

## IRIDIUM.

Symbol, . . . . .	Ir
Equivalent, . . . . .	98·68
Specific gravity, . . . . .	18·68
Fusible before oxy-hydrogen blowpipe.	

Iridium is found only in connexion with platinum, palladium, &c. When these metals are removed by aqua regia, iridium remains in connexion with osmium in the form of black scales. It is separated from osmium by being heated with chloride of sodium in a glass tube, through which chlorine gas is passed, one end of the tube dipping in ammonia. A chloride of iridium, plus chloride of sodium, remain in the tube, while the osmium is converted into osmic acid, which unites with ammonia. Iridium is got from its double chloride by heat. It is a white, brittle, very hard metal; not attacked by any acids, but oxidized by being heated with nitre. It is used to point gold pens, on account of its hardness and permanency.

It forms oxides, chlorides, &c.

## OSMIUM.

Symbol, . . . . .	Os
Equivalent, . . . . .	99·56
Specific gravity, . . . . .	10·
Fusible by oxy-hydrogen blowpipe.	

Osmium is obtained from its solution in ammonia by heating it. It is obtained in plates of a bluish-white colour. It burns when heated to redness, yielding osmic acid. It forms three oxides, viz., protoxide, sesquioxide, and osmic acid.



## PART III.

# ORGANIC CHEMISTRY.

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THE elements of organic and inorganic matter are precisely the same, and the difference between them consists entirely in the arrangement of these elements.

The number of the elements of organic matter, does not exceed fourteen or fifteen ; and their order is as follows, viz. : carbon, oxygen, hydrogen, nitrogen, sulphur, phosphorus, potassium, calcium, sodium, silicon, manganese, magnesium, chlorine, iron, and fluorine.

The mode of union of these elements, to form matter, is not known. In Inorganic Chemistry, it has been seen that combinations take place by pairs of elements. Thus, nitrogen and oxygen unite to form a binary compound, called nitric acid ; and potassium and oxygen unite to form another binary compound, potassa ; and again these two binary compounds unite, to form a double binary compound, which is the salt, nitrate of potassa. But no such method seems to take place in organic matter. The union of the elements to form bodies, no matter how complex, seems to be simultaneous.

The material of this part of chemistry may be divided into organized and organic bodies.

By an organized body, is meant one which has a specific form, the type of which is a cell, and which is capable of

producing the same forms. The lowest orders of plants, and the most perfect animals, are alike organized bodies.

By an organic body, is meant one which is the product of an organized body, as starch, sugar, gum, &c.

To these two classes may be added a third, viz.: those resulting from the chemical actions of other substances on either of the above; as alcohol, obtained from reactions on sugar, which is the product of an organized body.

The study of Organic Chemistry is comprised under the following general heads:

*Compound Radicals*, performing the functions of elementary bodies. Of this class, cyanogen will now be familiar to the student. It is a bicarburet of nitrogen, and yet enters into combinations and comports itself, precisely as the element chlorine.

*Organic Salt bases*. This class is made up principally of the alkaloids, as morphia, strychnia, &c.

*Organic Acids*. Some of these are compounds of known hypothetical radicals, as acetic, aldehydic, &c.; while others are as yet not determined.

*Neutral Non-nitrogenized bodies*. These contain hydrogen and oxygen in the proportion to form water. Starch, gums, sugar, &c., are included in this class.

*Neutral Nitrogenized bodies*. This includes all the protein compounds, besides the gelatin, neurine, and hematin groups of bodies.

*Carbo-Hydrogens*, both acids and bases.

*Fatty Substances*.

*Compound Acids*, viz., those composed of two or more organic bodies, as sulphovinic acid.

*Colouring Matters*.

#### ANALYSIS OF ORGANIC BODIES.

As organic bodies cannot be made artificially by uniting their elements, the synthetical method of determining their

constitution therefore fails us, and we must rely entirely on analysis for a knowledge of their chemical compositions. All organic bodies decompose by heat, in the presence of oxygen, and in the process, different substances result. The following is the method now generally pursued. Oxygen is presented to the organic body, and heat applied; its carbon is thus converted into carbonic acid, and its hydrogen into water; and by having a known weight of the reagents, the absolute amount of the elements may be determined. When nitrogen is present, ammonia is also formed.

We shall now suppose that we have to analyze sugar, which must of course be perfectly pure, and entirely free from moisture; four, and seventy-five hundredths grains of it are taken, and presented to an oxidizing body, the best being the black oxide of copper, chemically the protoxide; which is well adapted for analysis, because when alone, it may be exposed to a white heat, without decomposition, while it very readily yields oxygen to the organic body being analyzed.

A glass tube, made of potassa, is now taken, because it is the most refractory of the glasses. The sugar, mixed with the oxide of copper is placed in this tube, and the whole accurately weighed, having been previously well dried. To this, which is called the combustion tube, is attached another containing dried chloride of calcium, to absorb the water which may be formed. This is also weighed. Lastly, to the end of the chloride of calcium tube, is attached an apparatus, consisting of bulbs, containing a solution of potassa, which will absorb the carbonic acid passing over, and form a solution of carbonate of potassa. The whole apparatus is air tight. Heat is now applied to the tube containing the copper and sugar; the latter is decomposed; its carbon takes oxygen from the oxide of copper, and forms carbonic acid in the proportion of 16 grains of oxygen to 6 grains of carbon. The hydrogen of the sugar takes oxygen also, and forms water,

every 9 grains of which contain 1 grain of hydrogen. The carbonic acid and the water are absorbed, the first by the solution of potassa, and the last by the chloride of calcium.

After the process is finished, the chloride of calcium tube and the potash bulbs are weighed: the gain in the former will indicate the amount of water; in the latter, the amount of carbonic acid. From these data, the amount of carbon and hydrogen may readily be calculated. Thus, 22 is the equivalent number for carbonic acid, and 6 for carbon; therefore  $\frac{6}{22}$  or  $\frac{3}{11}$  of the whole weight of acid indicated by the increased weight of the potash bulbs, will give the absolute amount of carbon; and as 9 is the equivalent for water, and 1 for hydrogen,  $\frac{1}{9}$  of the whole increased weight of the chloride of calcium tube (which is due to water), will give the absolute amount of hydrogen. Having thus ascertained the weight of the carbon and hydrogen in the sugar, their sum subtracted from the whole weight of the sugar, will give the amount of oxygen. The following calculations are the results of experiment.

Quantity of sugar used, - - - - -	4.750 grains.
Potash apparatus weighed after experiment, -	781.13
“ “ “ before experiment, -	773.82
<hr/>	
The difference in weight due to Carbonic Acid, -	7.31
Chloride of Calcium tube after experiment, -	226.05
“ “ “ before experiment, -	223.30
<hr/>	
The increase in weight due to water, - -	2.75

Now, if 7.31 grains be carbonic acid,  $\frac{6}{22}$  or  $\frac{3}{11}$  of that will be carbon,

Therefore, - - -  $7.31 \times \frac{3}{11} = 1.994$  grains Carbon.

And if 2.75 be water,  $\frac{1}{9}$  of that will be hydrogen.

Therefore, - - -  $2.75 \times \frac{1}{9} = 0.3056$  grains of Hydrogen.

If we now add the weight of Carbon, 1.994

to the weight of water, - - - 0.3056

and subtract the sum, - - - 2.2996 grains

from the original weight of sugar, 4.7500

we shall get - - - - 2.4504 grains,

which is the amount of oxygen.

We can also obtain the relative proportions of the constituents in 100 parts by making the ratio as follows :

Grs. Sugar.		Grs. Sugar.		Grs. Carbon.		Grs. Carbon.
4.75	:	100	:	1.994	:	41.98

The same proportions will give 6.43 grs. for hydrogen, and 51.59 grs. for oxygen.

#### ESTIMATION OF NITROGEN IN ORGANIC COMPOUNDS.

When the body to be analyzed contains nitrogen, an alkali is added, for the purpose of converting all the nitrogen into ammonia. In addition to the apparatus for the non-nitrogenized, another set of bulbs containing chlorohydric acid is used. The ammonia is thus converted into the chloride of ammonium. To this, in solution, the bichloride of platinum is added, and a precipitate of the double salt, viz., the double chloride of platinum and ammonium, is formed. This is collected, dried, and weighed. It is then heated to drive off all the chlorine and ammonium, and the loss of weight which the residue indicates, will give the necessary data for calculating the amount of nitrogen.

#### ESTIMATION OF SULPHUR.

When bodies contain sulphur, the process consists in con-

verting it into sulphurous acid, and then oxidizing this by means of nitric acid. In this way sulphuric acid is obtained, which may be removed by a salt of baryta, the precipitate washed and dried, and the amount of sulphur then calculated.

## SECTION I.

### NON-NITROGENIZED NEUTRAL BODIES.

THIS class of bodies is remarkable for the isomerism of its members, and for their containing hydrogen and oxygen in the proportions for forming water.

TABLE OF NON-NITROGENIZED NEUTRAL BODIES.

Cellulose, - - - - -	$C_{24}H_{42}O_{31}$
(With this are found lignin and other encrusting matter.)	
Amylaceous bodies:	
Common Starch, - - - - -	$C_{12}H_{10}O_{10}$
Lichen Starch, - - - - -	$C_{12}H_{10}O_{10}$
Inuline, - - - - -	$C_{24}H_{21}O_{21}$
Dextrine, - - - - -	$C_{12}H_{10}O_{10}$
Gum Arabin, - - - - -	$C_{12}H_{11}O_{11}$
Cane Sugar:	
Crystallized, - - - - -	$C_{12}H_{11}O_{11}$
Dry, - - - - -	$C_{12}H_{10}O_{10}$
Grape Sugar, or Glucose:	
Crystallized, - - - - -	$C_{12}H_{14}O_{14}$
Dry, - - - - -	$C_{12}H_{12}O_{12}$
Lactine, or Sugar of Milk,	
Crystallized, - - - - -	$C_{12}H_{12}O_{12}$
Mannite, - - - - -	$C_6H_7O_8$



*Cellulose*.— $C_{24}H_{21}O_{21}$ . This is the basis of all plants; it is the material for forming the cell walls. It is distinct from lignin, or wood, which is only an incrustation without and within the cell walls, by which means the cells themselves are obliterated and stiffness conferred on the wood.

Cellulose is a ternary compound, containing carbon, hydrogen, and oxygen. The last two in the proportions for forming water.

Lignin is found nearly pure, as linen or cotton. It is tasteless, inodorous, insoluble in water or alcohol. Strong sulphuric acid converts it into an adhesive gummy substance resembling dextrine. The solution is rendered pure by adding lime to neutralize the acid, and then filtering. If previous to neutralization it be boiled for a few hours, and water be added slowly, the solution will be found to contain grape sugar.

#### AMYLACEOUS BODIES.

1. *Common Starch*.— $C_{12}H_{10}O_{10}$ . Starch is not an organized body, it is only the product of an organism. It results from cell action on dextrine, the nutritive principle of plants, by which means it is deposited in their seeds, roots, tubers, &c., for the nourishment of future plants and the propagation of the species.

The starch is deposited in cells, hence its granular form; and as these cells vary both in size and shape in every plant, we therefore have the different varieties of starch. We thus have sago from the *Sagus rumphii*; tapioca from the *Jatropha manihot*; arrow-root from *Maranta arundinacea*; potato-starch, wheat-starch, and many others; all varying both in the size and form of the granules.

Starch is prepared by one great general method from all. This consists in grating, rasping, or grinding the material containing it, whether seed or root or pith, and throwing it

into cold water and washing. In a short time the starch falls in the form of granules; these consist of small cells, with the starch deposited within them. Starch is insoluble in hot or cold water; it is also insoluble in alcohol and other liquids which do not effect its decomposition.

It is apparently soluble in boiling water, because the water, by endosmose, enters its envelope, and ruptures it; and thus minutely dividing its contents, the whole assumes a gelatinous and translucent condition. Its apparent solubility is therefore only due to a state of minute division. It has been said, that  $\frac{5}{100}$  of 1 per cent. of starch are soluble; but this is due very probably to impurities. Hydrated starch is called *amidine*; when exposed in thin layers it becomes hard, and on again being placed in water it assumes its gelatinous condition. The test for starch is free iodine, which strikes a deep blue colour with it. Starch is also precipitated by metallic oxides, alcohol, and tannic acid.

*Lichen Starch.*— $C_{12}H_{10}O_{10}$ . This is obtained from Iceland moss by boiling in water. It differs very little from common starch.

*Inuline.*— $C_{24}H_{21}O_{21}$ . This peculiar variety of starch is found in the dahlia root and many other plants. It is obtained in the usual way. It is not precipitated by tannic acid; and iodine strikes a brown precipitate with its hydrate instead of a blue one.

*Dextrine.*— $C_{12}H_{10}O_{10}$ . Dextrine is found in the cells of the simplest and most complex plants. It may be dissolved out from the radicle of a growing plant, as a potato, by simply throwing it in water. It may also be prepared in the laboratory, by the addition of dilute sulphuric acid to hydrated starch, and boiling for a short time; the starch loses its gelatinous consistency and becomes thin; or in other words, it is converted from an insoluble to a soluble substance. In this condition iodine has no reaction on it at all.

If the boiling of the starch with sulphuric acid be con-

tinued for some time, the dextrine is first formed, and this again is converted into grape sugar.

If a seed which is nearly all starch be planted, it grows; a plumule starts up to constitute the stem; this plumule contains dextrine, which it obtained from the starch of the seed by the chemical action of the cells of that seed.

It is obvious that the material necessary for the growth of the plant must be soluble, and as dextrine is soluble, it is suited for that purpose. The process by means of which this is accomplished, is called germination.

During this action a nitrogenized body is developed, called diastase, the constitution of which has never been determined; and this complex body communicates a force to the starch, called *katalytic*, which force confers solubility on the starch, although no change has taken place in the number or proportion of its elements. For the process of germination, certain requisites are necessary, viz., water, a certain amount of heat, oxygen, and the presence of the germ. These requisites are obtained in the spring in our northern climates. This process is also artificially imitated in malting. The germination is allowed to go on for a certain time under the proper conditions, until the plumule becomes about one inch in length. More heat is then applied; this destroys the cell action, and the process ceases; and now it will be found that all the starch has been converted into dextrine and sugar. To prove this, all that is necessary to do, is to make a decoction of the malt, and apply iodine, the test for starch, when no blue precipitate will be produced.

The reactions of the starch seem to take place on or with the water alone, although a katalytic body must be present to excite or communicate the force necessary for these reactions. The katalytic body itself, whether acid or diastase, does not enter into the round of affinities at all.

Dextrine is used in the arts as a substitute for gum. It

was called dextrine because it possesses the property of polarizing a ray of light to the right.

Dry starch heated to  $400^{\circ}$  is converted into dextrine; thus prepared, it is called British gum, much used by hatters.

Dextrine is convertible into starch in the plant after a certain time, and this starch is again deposited in seeds or roots for the development of future plants.

*Gum Arabin.*— $C_{13}H_{11}O_{11}$ . Gum is the product of numerous species of the *acacia*; the bark of the tree cracks, and the juice exudes on its surface, and there concretes. It is soluble in cold water, forming a clear, viscid solution, from which arabine, the pure gummy principle, is precipitated by alcohol and subacetate of lead. It is convertible into sugar by a ferment.

*Cerosin*, another kind of gum, is got in the cherry, plum, and peach. It is not soluble in water, but it is converted into arabine, and thus made soluble, by being boiled in water.

*Bassorin*, another variety of gum, is found in tragacanth, the product of the *Astragalus*. It is insoluble in water, and is not convertible into arabine by boiling; this serves to distinguish it.

#### SUGAR.

*Cane Sugar; Crystallized.*— $C_{12}H_{22}O_{11}$ . This is found in the juice of many grasses, in the sap of forest trees, in the root of the beet, and in many other plants. It is got most abundantly from the sugar cane, *Saccharum officinale*, by expressing the juice, mixing with lime, evaporating and crystallizing. The lime removes any acid, and by afterwards boiling before evaporating, the albumen it contains is coagulated. When cooling, it is stirred to make it granular. Sugar is refined by boiling it in lime-water and blood, and then evaporating in vacuo.

Cane sugar crystallizes in transparent oblique rhombic prisms. Heated, it melts, and solidifies on cooling into an amorphous mass, called barley sugar; heated still farther, it is converted into a substance called *caramel*, which is isomorphous with cane sugar.

Cane sugar is converted into grape sugar by acids and a ferment.

*Grape Sugar or Glucose.*— $C_{12}H_{22}O_{11}$ . This sugar is found in most fruits; it is also the product of the action of dilute acid, or a ferment on cane sugar, and of the action of diastase on starch. It is also found most abundantly in the urine of diabetic patients.

Honey is another form of grape sugar.

Grape sugar, when pure, is white, granular, and uncrystallizable; in the mouth its taste is cooling and sweet. It differs from cane sugar by being less sweet and less soluble in water, and by forming warty, butyroidal masses instead of crystallizing.

The test for grape sugar is the protoxide of copper. Thus, add to a solution of grape sugar sulphate of the protoxide of copper and an alkali, as caustic potassa; a beautiful blue solution will be obtained with both cane and grape sugar. But, on heating that containing the grape sugar, a copious red precipitate is obtained, while the other undergoes comparatively but very little change. The red precipitate is due to the formation of the sub or dioxide of copper, by the carbon and hydrogen of the sugar taking oxygen from the protoxide, and thus reducing it.

Grape sugar undergoes the vinous fermentation, and all other sugars must first be converted into grape sugar, before they will ferment.

*Lactine, or Sugar of Milk; Crystallized.*— $C_{12}H_{22}O_{11}$ . This exists in the milk of all the mammalia. It is obtained by evaporating the whey to a syrup, and allowing the lactine to slowly crystallize out. It forms white prisms. It is slowly

soluble in water, has a feebly sweet taste, and feels gritty under the teeth. It is convertible into grape sugar by acids or ferment.

*Mannite*.— $C_6H_7O_6$ . This is the chief constituent of manna, the product of the *Fraxinus ornus*, or flowering ash. It is prepared by boiling manna in alcohol, and then filtering. On cooling, the mannite crystallizes out. Mannite is incapable of undergoing the vinous fermentation, or of being *converted into grape sugar*.

#### PRODUCTS ARISING FROM CHEMICAL REACTIONS ON THE PRECEDING SUBSTANCES.

##### ACTION OF NITRIC ACID.

*Oxalic Acid*.— $C_2O_3$ , or  $CO + CO_2$ . This acid is always developed when strong nitric acid is brought into contact with sugar, or any of the bodies in the preceding part of the section, except gum and sugar of milk. Heat is necessary for the process; during which copious red fumes are given off, owing to the escape of nitric oxide, while the rest of the oxygen of the nitric acid converts the sugar into oxalic acid. The other products of this reaction are water and nitric oxide. The acid crystallizes out from its solution by evaporation. These crystals contain 3 equivalents of water; their formula would be  $C_2O_3 + 3HO$ . But, by carefully heating the acid, 2 equivalents of water may be driven off, leaving the acid in combination with only 1 equivalent of water; from which it cannot be separated without destroying the body. It is soluble in 8 parts water at  $60^\circ$  F., and its own weight of hot water. It is soluble, also, in alcohol. It is intensely sour, and has a powerful acid reaction.

The sorrel, rhubarb, &c., yield this acid, in which it exists as the binoxalate of potassa.

The test for oxalic acid is lime, with which it forms a very



insoluble white precipitate, the oxalate of lime. This salt is soluble, however, in acids.

Sugar of milk and gum yield *mucic acid*, by the action of nitric acid on them.

*Pyroxylin*.— $C_{12}H_9O_9 + 2NO_5 + HO$ . Lignin or pure cotton, acted on by nitric acid, produces a body very explosive in its nature, called gun-cotton. It is best prepared by developing the strong nitric acid in contact with the cotton. This is readily done by adding sulphuric acid to a mixture of the cotton and nitrate of potassa. The cotton has apparently suffered no change; but, when dried and fired, it explodes with the utmost violence, and the results of its combustion are carbonic acid, water, and hyponitrous acid. It is a nitrate of lignin, and its formula, according to analysis, is  $C_{12}H_9O_9 \cdot 2NO_5 + HO$ .

Pyroxylin is not acted on by water, nor by alkalies, but, in certain conditions, it is soluble in ether. This solution is called *collodion*. It has been very much used for an adhesive plaster, its adhesive properties being due to the rapid evaporation of the ether, leaving a thin film of lignin on the surface.

*Xyloidine*.— $C_6H_4O_4 \cdot NO_5$ . This is made by the action of nitric acid on paper. It is analogous to pyroxylin.

#### VINOUS FERMENTATION AND ITS PRODUCTS.

Vinous fermentation is the name given to that process which grape sugar undergoes in the presence of a nitrogenized substance undergoing change, and which results in the production of alcohol and carbonic acid.

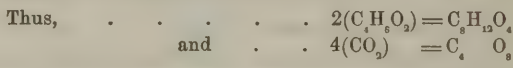
From katalysis it differs, the latter term being applied to those changes produced by a second body which itself is undergoing no metamorphosis. Thus spongy platinum fires hydrogen by katalysis, and yet the platinum is totally unaltered.

According to Liebig, the molecules of the ferment are capable of communicating an intestinal movement in a stable body, similar to that going on within itself, and which we call putrefaction when it occurs in such nitrogenized substances as albumen, &c.

Another view of the changes occurring in a fermenting body is, that organic growths are developed, which growths or plants do nothing more than remove the carbonic acid from the sugar, and leave the alcohol. These organic growths are called the yeast plant, and are nothing more than successive developments of cells, one on the other, expressed by the term *exogenous*. That these cells do exist has been satisfactorily proved by the microscope; but whether they have anything to do with the production of the alcohol, remains yet to be demonstrated.

*The conditions necessary for fermentation*, are sugar, which must be in the state of solution, a temperature of  $80^{\circ}$  F., and the presence of a fermenting body, which is generally diastase, but which has never been determined as regards its chemical constitution. When these conditions are obtained, an intestinal movement goes on very rapidly, which results in the production of carbonic acid, which escapes, and alcohol, which remains in solution.

The composition of alcohol is expressed by the formula  $C_4H_6O_2$ ; it is produced by one equivalent of grape sugar breaking up into two equivalents of alcohol and four equivalents of carbonic acid, the formula for which is  $CO_2$ .



The sum expresses the formula for grape sugar,  $C_{12}H_{22}O_{12}$

It is grape sugar alone which yields alcohol, and when any other sugar, or any amylaceous body is used, it is first converted into glucose, or grape sugar, and then into alcohol.

*Alcohol* is got from the liquid in which it remains dissolved, after fermentation, by distillation; repeated distillations give proof spirit, which contains 15 per cent. of water, and has a specific gravity of  $\cdot 835$ . Pure or absolute alcohol is got by distilling the proof spirit with chloride of calcium, which absorbs all the water, and leaves anhydrous alcohol. Its formula is  $C_4H_6O_2$ , or, as representing its constitution,  $C_4H_5O + HO$ , that is, the *hydrated oxide of ethyle*.

Pure alcohol is a colourless, limpid liquid, of a pungent, agreeable taste and odour; its specific gravity at  $60^\circ$  F. is  $\cdot 793$ . It is very inflammable, burning with a pale bluish flame, without smoke, and has never been frozen. The products of the combustion of alcohol are water and carbonic acid. It is miscible with and has a great affinity for water; it is one of the greatest solvents in nature.

#### FERMENTED LIQUORS.

*Wine*.—The juice of the grape naturally undergoes the vinous fermentation, owing to the presence in it of a nitrogenized body existing in the skin, which is very prone to putrefaction. This juice, which is called *must*, is simply set aside in large vats; the nitrogenized matter absorbs oxygen, that is, putrefies, and this then excites fermentation in the rest of the liquid, causing the escape of carbonic acid, and the conversion of all the grape sugar into alcohol. During the fermentation of the juice a salt is deposited in the bottom, owing to its great insolubility in alcohol, and its comparative insolubility in water: this is called *argol*; it is the acid tartrate of potassa, improperly called the bitartrate. By this means the acid of the juice is removed; but no such result takes place in the juices of currants, gooseberries, &c., because their salts, viz., the citrates and malates, are soluble in water and alcohol, and remain undeposited.

If wine is taken out of the vats before the fermentation is finished, put in bottles, and corked, the process will still go on under pressure, and the carbonic acid is confined in the wine; hence, when these bottles are opened, the wine sparkles, owing to the escape of the acid: this is called champagne.

*Malt Liquors* are those made by exciting the vinous fermentation in an infusion of malted barley, which, as has been said, contains sugar and dextrine, and a body called diastase.

The infusion first made, called wort, is boiled, then cooled, and allowed to ferment. By treating it in various ways, the different varieties of malt liquors, viz., ale, beer, porter, &c., are made.

*Distilled Liquors* are those made from fermented liquors by distillation; brandy from wine, whiskey from barley wort, &c. To these liquors are added different volatile oils, to give flavour and taste.

#### PRODUCTS OF THE ACTION OF ACIDS ON ALCOHOL.

*Ether*.—When alcohol is presented to acids, and heat applied, ethers are obtained.

If sulphuric acid be mixed with alcohol, and placed in a retort, in the proportion of equal weights of each, and heat applied until the liquid boils, a colourless, highly volatile liquid called ether, and sulphuric ether, distils over.

This liquid contains no sulphuric acid at all. It is a colourless, transparent, fragrant liquid. Its specific gravity is  $\cdot 720$  at  $60^{\circ}$  F.; it boils at  $96^{\circ}$  at the level of the sea, and when exposed to intense cold it freezes. It volatilizes very rapidly, and when dropped on the hand excites the sensation of severe cold, on account of its rapid evaporation. It is combustible, burning with a white flame, and generating water and carbonic acid.

Ether is miscible with alcohol in all proportions, but not

with water. Of this latter it will take up one-tenth, and water will take up one-tenth of ether.

## COMPOUND ACIDS.

*Sulphovinic Acid*.— $C_4H_5O, 2SO_3 + HO$ . Ether contains no sulphuric acid; but during the manufacture of it an acid is developed, differing from sulphuric acid, called sulphovinic acid. This acid is a body resulting from the chemical union of sulphuric acid with a base supposed to exist in the alcohol, called ethyle. It is developed at the heat of  $300^\circ$ ; and if now baryta be added to the liquid, no precipitate will be obtained; proving that the sulphuric acid is now in combination with a base for which it has a stronger affinity than it even has for baryta. The base is the oxide of ethyle, the formula of which is  $C_4H_5O$ . This is ether; and the hydrated oxide of this is alcohol, the formula for which is  $C_4H_5O + HO$ . Now part of the acid first takes the water, giving  $SO_3HO$ ; and another part of the acid then takes the oxide of ethyle, giving  $SO_3, C_4H_5O$ ; and these two sulphates united are the compound body, sulphovinic acid. That is,  $C_4H_5O, SO_3 + HO$ ,  $SO_3 = C_4H_5O, 2SO_3 + HO$ , which is the formula for sulphovinic acid.

*Phosphovinic acid* is obtained under precisely the same circumstances as the preceding; it has the same constitution, and its formula is  $C_4H_5O, PO_5 + HO$ .

There are other compound acids, the constitution of which may be readily inferred.

All these acids are decomposed at higher temperatures than those at which they are formed; and their base, which is the oxide of ethyle or ether, is allowed to distil over from the retort into the receiver. The process for making ether may be rendered continuous by keeping up a constant addition of alcohol, which supplies a base to the sulphuric acid, and thus

keeps up a supply of sulphovinic acid in the retort as rapidly as it is decomposed. The heat should be kept, during the whole time, at about  $300^{\circ}$  F. The ether distils over with water, and two layers are thus formed in the receiver. The crude ether is readily separated from the water on which it floats; it is then purified by the addition of caustic potassa, and redistilled by the heat of warm water.

## ETHYLE.



Ether has been found, by analysis, to contain  $\text{C}_4\text{H}_8\text{O}$ . It resembles a base in its relation to acids, and is supposed to be the oxide of a metalloid or hypothetical radical called ethyle. Of these compound radicals none have ever been isolated but cyanogen and kakodyle; but their constitution is inferred almost as certainly from the compounds they form as if the bodies themselves had been isolated.

## OXIDES OF ETHYLE.

Ethyle, symbol Ae, . . . . .	$\text{C}_4\text{H}_8$
Oxide of Ethyle; Ether, . . . . .	$\text{C}_4\text{H}_8\text{O}$
Hydrate of the Oxide of Ethyle; Alcohol, . . . . .	$\text{C}_4\text{H}_8\text{O} + \text{HO}$

Ether and alcohol have already been treated of, and the salts of ethyle only remain.

## HALOID SALTS OF ETHYLE.

Chloride of Ethyle, . . . . .	$\text{C}_4\text{H}_8\text{Cl}$ , or AeCl
Bromide of Ethyle, . . . . .	$\text{C}_4\text{H}_8\text{Br}$ , or AeBr
Iodide, . . . . .	$\text{C}_4\text{H}_8\text{I}$ , or AeI
Cyanide, . . . . .	$\text{C}_4\text{H}_8(\text{Cy})$ , or $(\text{C}_4\text{N})$ , or AeCy
&c., &c.	



## OXY-SALTS OF ETHYLE.

Nitrate of Oxide of Ethyle, . . .	$C_4H_5O, NO_5$ , or $AeO, NO_5$
Hyponitrite “ “ . . .	$C_4H_5O, NO_3$ , or $AeO, NO_3$
Acetate, “ “ . . .	$C_4H_5O(C_2H_3O_2)$ , or $AeO, C_2H_3O_2$
Formiate, “ “ . . .	$C_4H_5O(C_2H, O_3)$ , or $AeO, C_2H, O_3$
Oxalate “ “ . . .	$C_4H_5O(C_2O_3)$ , or $AeO, C_2O_3$
Acid Sulphate, or Sul- phovinic Acid, }	$C_4H_5O, 2SO_3+HO$ , or $AeO, 2SO_3+HO$
&c., &c.	

*Chloride of Ethyle.*— $C_4H_5Cl$ . This, which is sometimes called hydrochloric ether, is prepared by distilling a mixture of chlorohydric acid and alcohol by a very gentle heat. Water distils over with it, from which it is purified by chloride of calcium. It is thin, without colour, very volatile, and has a garlicky odour, but also aromatic. Its sp. gr. is .874; it boils at  $52^\circ F.$ , and is taken up by water in the proportion of 1 part ether to 10 of water. Caustic potassa, in solution, converts it into chloride of calcium and alcohol. Thus  $KO+HO$  and  $AeCl$  yield  $KCl$  and  $AeO+HO$ , or  $C_4H_5O+HO$ .

*Bromide, Iodide, Cyanide, and Sulphuret of Ethyle.*—These are all prepared in the same general way, with slight modifications, and have the same general properties.

The iodide is the heaviest of them all, having a density of 1.92, and a boiling point at  $160^\circ F.$

*Nitrate of Oxide of Ethyle; Nitric Ether.*— $C_4H_5O, NO_5$ , or  $AeO, NO_5$ . This is made by presenting nitric acid in its nascent state, to the oxide of ethyle; because the acid is very readily decomposed, yielding up part of its oxygen, and being converted into hyponitrous acid. This result is also prevented by adding nitrate of urea to alcohol and distilling. Nitric ether is heavier than and is insoluble in water; it has an agreeable odour and a sweet taste.

*Hyponitrite of the Oxide of Ethyle; Nitrous or Hyponi-*

*trous Ether*.— $C_4H_5O + NO_3$ , or  $AeO, NO_3$ . By distilling a mixture of nitric acid and alcohol, a liquid is obtained containing hyponitrous ether and aldehyde; this latter results from the oxygen of the nitric acid taking hydrogen from some of the alcohol, that is, dehydrogenating it, and converting it into  $C_4H_3O + HO_3$ , while the hyponitrous acid then unites with the oxide of ethyle, forming a hyponitrite, and the two distil over together. This is the sweet spirits of nitre of the shops; it also contains alcohol.

To prepare pure hyponitrous ether, mix in the cold, hyponitrite of soda and alcohol, and then add sulphuric acid. The acid develops the oxide of ethyle, which displaces the soda in the hyponitrite of soda, and forms a hyponitrite of the oxide of ethyle, which distils over and leaves sulphate of soda in solution in the retort. Thus by symbols.  $NO_3NaO$  and  $C_4H_5O + HO$ , add  $SO_3$  and we get  $NO_3C_4H_5O$ , and  $SO_3 NaO + HO$ .

Prepared thus the liquid is yellow and extremely volatile; it is indeed the most rapidly volatilizing body known. It boils at  $62^\circ$ , and has a density of  $\cdot947$ . It is decomposed by potash into a hyponitrite of potash and alcohol. A mixture of hyponitrous ether and alcohol is pure sweet spirits of nitre.

*Acetate of Oxide of Ethyle; Acetic Ether*.— $C_4H_5O(C_2H_3O_3)$  or  $AeOC_2H_3O_3$ . This is prepared by heating in a retort, acetate of potassa, or soda, alcohol, and sulphuric acid. The reactions are the same as above, only that acetic acid is used instead of hyponitrous acid. It is fragrant, limpid, has a sp. gr. of  $\cdot890$ , boils at  $165^\circ$  F., and is decomposed by the alkalis into acetates and alcohol.

*Formiate of Oxide of Ethyle; Formic Ether*.— $C_4H_5O(C_2HO_3)$  or  $AeOC_2HO_3$ . This is made by distilling from a retort a mixture of formiate of soda, alcohol, and sulphuric acid. The reactions are the same as above. It is colourless, has a peculiar smell, a sp. gr. of  $\cdot915$ , and boils at  $133^\circ$  F.

*Oxalate of the Oxide of Ethyle; Oxalic Ether.*— $C_4H_5O$  ( $C_2O_3$ ) or  $AeO$ ,  $C_2O_3$ . This is obtained by distilling binoxalate of potassa, alcohol, and sulphuric acid from a retort. The reactions are the same as in the last three cases. The product is washed and redistilled to get it pure.

It is colourless, oily, aromatic, has a sp. gr. of 1.09, boils at  $363^\circ F.$ , and is decomposed by the alkalies into oxalates and alcohol. But with a solution of ammonia in excess, it gives oxamide and alcohol. Oxamide is a substance analogous to chloramide; its formula is  $C_2O_2NH_2$ ; it falls in the form of a white precipitate; when presented to a solution of an alkali it is decomposed into a carbonate of that alkali and ammonia, which remain in solution.

*Acid Sulphate of the Oxide of Ethyle; or Sulphovinic Acid.*— $C_4H_5O$ ,  $2SO_3$ ,  $HO$ , or  $AeO$ ,  $2SO_3HO$ . This body has already been spoken of when treating on the production of ether, by the action of sulphuric acid on alcohol.

*Heavy Oil of Wine.*—This is prepared by distilling in a retort  $2\frac{1}{2}$  parts of strong sulphuric acid, and 1 part of alcohol, of sp. gr. .835. Ether comes over at first, but in a short time a heavy oily liquid distils over, along with ether, sulphurous acid, and alcohol. When purified from these, it is a colourless or greenish oily liquid, heavier than water, with the odour of peppermint, and an aromatic taste. It is soluble in alcohol and ether. It is a sulphate of ether and a sulphate of a hydro-carburet, *etherole*. Its formula is  $C_4H_4$ ,  $SO_3 + C_4H_5O$ ,  $SO_3$ .

*Olefiant Gas.*— $C_2H_2$ . This is made by distilling from a retort a mixture of alcohol with an excess of sulphuric acid at  $320^\circ F.$

This is simply a hydro-carburet, very inflammable, burning with much light, and yielding water and carbonic acid. Its density is .981; 100 cubic inches weigh 30.57 grains.

With chlorine it unites, producing a heavy oily liquid, of a sweetish taste and an agreeable odour. This was called Dutch

liquid, but more properly it is a chloride of olefiant gas. Its formula is  $C_4H_4Cl_2$ .

Olefiant gas also unites with bromine and iodine, &c., to produce bodies similar to Dutch liquid.

PRODUCTS OF THE ACTION OF CHLORINE ON ALCOHOL,  
ETHER, ETC.

*Chloral*.— $C_4Cl_3O + HO$ . When a current of dry chlorine gas is made to pass through anhydrous alcohol, and heat applied, chloral is got. During the process, hydrochloric acid is formed, by the removal of two equivalents of hydrogen, which unite with the chlorine, and then the rest of the hydrogen is substituted by the chlorine.

It contains the same elements, with the exception that chlorine takes the place of hydrogen, and the same arrangement as the hydrated oxide of acetylene, a substance to be hereafter described, called *aldehyde*. The formula for chloral is  $C_4HCl_3O_2$ , or, better,  $C_4Cl_3O + HO$ .

It is a thin, oily, colourless liquid, with a penetrating odour, exciting tears. Its specific gravity is 1.5, and its boiling point  $200^\circ$ . It is soluble in water, alcohol, and ether. Solutions of caustic alkalies, with heat, decompose it into chloroform and a formiate of the base.

When chlorine is presented in the same way to pure ether, the same kind of substitution takes place, until finally the whole of the hydrogen is removed, giving rise to a series of compounds commencing with *chlorethral*,  $C_4H_4ClO$ .

Thus we may have the table as follows:

Ether,	$C_4H_6O$ ;	now present chlorine,
and we get	$C_4H_5ClO$	and chlorohydric acid,
then,	$C_4H_3Cl_2O$	“ “
then,	$C_4H_2Cl_3O$	“ “
then,	$C_4HCl_4O$	“ “
then,	$C_4Cl_5O$	“ “

Light is necessary for these processes to go on.

*Chloroacetic Acid*.— $C_4Cl_3O_3$ . Acetic acid may have its hydrogen displaced in the same way. Substitute chlorine for hydrogen in the formula for acetic acid,  $C_4H_3O_3$ , and we get  $C_4Cl_3O_3$ , a body called *chloroacetic acid*.

## PRODUCTS OF THE ACTION OF OXYGEN ON ALCOHOL.

### ACETYLE.

When alcohol is oxidized in the open air, that is, burned, the products of the combustion are water and carbonic acid; but, under certain circumstances, the hydrogen alone of the alcohol may be oxidized, leaving the carbon untouched. The result of the dehydrogenation of the alcohol gives rise to certain compounds, inferred to have one common base, called *acetylene*. Acetylene results from ethylene, by depriving the latter of two equivalents of hydrogen, and it differs from ethylene by having compounds which are acids instead of bases.

### ACETYLENE SERIES.

#### $C_4H_2$ .

Acetylene, . . . . .	$C_4H_2$
Hydrated Oxide of Acetylene,	$C_4H_2O + HO$ Aldehyde.
Acetylous Acid, . . . . .	$C_4H_2O_2 + HO$ Aldehydic Acid.
Acetylic Acid, . . . . .	$C_4H_2O_3 + HO$ Acetic Acid.
Chloroacetic Acid, . . . . .	$C_4Cl_2O_3 + HO$ .
Acetal, . . . . .	$C_4H_2O + HO + C_4H_5O = C_8H_5O_2$ .
Acetone, . . . . .	$C_4H_4O$ .

Acetylene is a radical, susceptible of oxidation precisely as sulphur and phosphorus; the compounds formed, resemble the acids; they are, indeed, acids, as much so as sulphuric and phosphoric. Acetylene is unlike ethylene, because the latter, like a metal, forms bases which unite with acids, while

the former forms acids which will unite with bases. Thus acetic acid, which is the hydrated teroxide of acetylene, will unite with the oxide of ethylene itself, and form a salt called acetic ether.

Pure alcohol is not changed by exposure to the air, but when it is presented to any agent capable of effecting a union between hydrogen and oxygen, as spongy platinum, or a ferment, the alcohol breaks up into compounds by virtue of the removal of its hydrogen, the first of which is aldehyde.

*Aldehyde; Hydrated Oxide of Acetylene*,  $C_4H_3O + HO$ .—This is made on the principle of imparting oxygen to the hydrogen of the alcohol or ether in such a way that two equivalents of hydrogen may be lost. This is readily done by having a coil of fine platinum wire around the wick of an alcohol lamp; as the vapours of the alcohol escape from the wick, the platinum wire becomes red hot, and the hydrogen is consumed partially, giving rise to the production of aldehyde and acetic acid. It may also be made by adding chromic acid to alcohol in excess; the acid imparts oxygen to the alcohol; but the union is so rapid as to fire the alcohol in nearly all cases, and the only results of the combustion then, are carbonic acid and water. To avoid this, the chromic acid should be presented in only very small quantities; and the method now resorted to is, to distil in a retort a mixture of dilute sulphuric acid, alcohol, and bichromate of potassa, or the bioxide of manganese. The aldehyde is passed into a cold receiver, and then redistilled with chloride of calcium to purify it. When pure, it is a limpid, very mobile, colourless liquid, having the odour of sweet apples. It reduces oxide of silver to the metallic condition, which is a test for it, and the aldehyde is itself converted into aldehydic acid. It results from the dehydrogenation of alcohol, hence the name *aldehyde*. It is chemically the hydrated oxide of acetylene.

*Aldehydic Acid, or Acetylous Acid*.— $C_4H_3O_2 + HO$ . This



is obtained by the action of aldehyde on the oxide of silver, with the aid of heat; the aldehyde is converted into aldehydic acid, while the silver is reduced to the metallic condition. It is the hydrated bioxide of acetylene.

*Acetylic or Acetic Acid.*— $C_4H_3O_3 + HO$ . Pure alcohol is, as has been said, not changed by exposure, but if it be presented to spongy platinum, it is converted into acetic acid. The platinum is said to act katalytically, that is, it disposes the oxygen of the air to unite with the alcohol, and in this way its hydrogen is removed and oxygen is added to it. Acetic acid also results from a natural process called acetous fermentation. Dilute alcohol or wine, or any substance containing alcohol, exposed to the air with a fermenting body, becomes oxidized, and is converted into acetic acid. It is thus made artificially: take a solution of alcohol, add yeast, and have a temperature of  $80^{\circ}$  F.; oxygen will be absorbed and acetic acid will be left.

No carbonic acid is given off. It is not a process of *fermentation*, but of *oxidation*. By symbols, alcohol,  $C_4H_5O + HO$ , or  $C_4H_6O_2$ ; present 4 equivalents of oxygen to this, and we have  $C_4H_6O_2$  and  $O_4$ , yielding  $C_4H_3O_2 + O + 3HO$ , or  $C_4H_3O_3 + 3HO$ , which last is the formula for acetic acid, with two additional equivalents of water.

The best vinegar is made from wine by spontaneous acetification. It is nothing more than a dilute solution of acetic acid in water. The acetification is hastened by having a large surface, and in this way it can be made in a few days. Take tall tanks perforated in the bottom with small holes, fill the tanks with shavings, and pour on these a solution of whiskey and yeast; as the liquid trickles through, pour it in again, and in a few days it will be found that a perfectly pure solution of acetic acid will be formed.

Acetic acid is also made by the distillation of wood in iron retorts. The liquid that passes over contains other bodies,

but the acid is removed by saturating with lime and adding then a solution of sulphate of soda; double decomposition takes place, giving acetate of soda in solution, and sulphate of lime precipitated. The strongest acetic acid is now obtained by distilling the acetate of soda with strong sulphuric acid. This acid, obtained thus in solution by evaporation, crystallizes, that is, freezes below  $60^{\circ}$  F., constituting solid acetic acid. It dissolves in water, alcohol, and ether. It cannot exist as an acid without water. Chemically, it is the hydrated teroxide of acetylene; its formula is  $C_4H_3O_3 + HO$ . It forms a vast number of salts, which in their bases substitute the one equivalent of water, which is basic. Many of its salts have been described in Inorganic Chemistry. Acetic acid exists as acetate of potassa in nearly all plants; it is the source of the carbonate of potassa of commerce.

#### SALTS OF ACETIC ACID.

*Acetate of Potassa.*— $KO, C_4H_3O_3$ . This salt is known in pharmacy, as *sal diureticus*. It occurs in white foliated crystals, soluble in water and alcohol, and extremely deliquescent.

*Acetate of Soda.*— $NaO, C_4H_3O_3 + 6HO$ . The mode of preparing this has been described under the head of Acetic Acid.

*Acetate of Lead.*— $PbO, C_4H_3O_3 + 3HO$ . This salt is prepared by dissolving litharge in acetic acid. It occurs in confused crystals resembling loaf-sugar, hence the name sugar of lead. It is soluble in water and alcohol, and has a sweet astringent taste.

*Acetate of Copper.*— $CuO, C_4H_3O_3 + HO$ . This is prepared by dissolving the subacetate of copper, *verdigris*, in hot acetic acid. It forms beautiful dark-green crystals, which are soluble in water and alcohol.

*Chloroacetic Acid.*— $C_4Cl_3O_3 + HO$ ; is made by the action of chlorine gas on dry acetic acid. It is a case of simple

substitution, the chlorine taking the place of the hydrogen. The materials must be introduced dry into a bottle, and then exposed for some time to the solar rays; the chloroacetic acid falls to the bottom and forms on the sides in crystalline masses. These crystals are impure, containing acetic, chlorohydric, and carbonic acids.

*Acetal*.— $C_8H_9O_3$ . This substance is obtained by the slow oxidation of alcohol by means of spongy platinum; obtained in this way, it has to be purified from acetic acid and aldehyde. When pure, it is a thin, colourless liquid, with a pungent, agreeable odour, and soluble in water and alcohol.

*Acetone; Pyroacetic Spirit*.— $C_4H_4O$ . This is prepared by distilling acetate of lead in an earthenware retort; acetone and carbonic acid collect in the receiver. When pure, it is a colourless, limpid fluid, with a peculiar odour, a density of .792, and a boiling point at  $132^\circ$  F. It burns with a white flame; it is soluble in water, alcohol, and ether.

#### ACTION OF ARSENIC ON ACETIC ACID.

##### KAKODYLE.

Symbol Kd.  $C_4H_5As$ .

By distilling a mixture of acetate of potassa and arsenious acid, a substance was obtained long known under the name of the fuming liquor of Cadet. M. Bunsen demonstrated that this was the oxide of a compound radical, called by him kakodyle, which he isolated. He also discovered many compounds of it; but, as kakodyle and its compounds are extremely poisonous, no one has, as yet, undertaken any further examinations. It is of no importance to the student, except that it has been isolated, thereby affording the analogical proof of the existence of the other compound radicals that have not been isolated.

TABLE OF SOME KAKODYLE COMPOUNDS.

Kakodyle (symbol Kd), . . . . .	$C_6H_6As$
Oxide of Kakodyle, . . . . .	$KdO$ ,
Chloride of " . . . . .	$KdCl$
Chloride of Kakodyle and Copper, . . . . .	$KdCl + CuCl$
Perchloride of Kakodyle, . . . . .	$KdCl_3$
Bromide of " . . . . .	$KdBr$
Iodide of " . . . . .	$KdI$
Kakodylic Acid, . . . . .	$KdO_3$
&c., &c.	

As the above bodies are of no practical importance, they are not treated of, and the student is referred to the larger books for them.

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## SECTION II.

### SUBSTANCES RESEMBLING ALCOHOL.

#### METHYLE, AND ITS COMPOUNDS.

IN the destructive distillation of ligneous, and, indeed, many non-nitrogenized substances, pyroligneous acid, and an ethereal substance called wood spirit, wood naphtha, and pyroxylic spirit, are obtained. Soda removes the pyroligneous acid, while the wood spirit is purified by adding lime, to remove any acid it may contain, and chloride of calcium, to remove moisture.

This is another alcohol, containing a compound salt radical called methyle, the oxide of which is an ether, forming salts with acids, and the hydrated oxide of which is methylic alcohol.

## METHYLE SERIES.

Symbol Me.  $C_2H_3$ .

Methyle, . . . . .	$C_2H_3$ or Me
Oxide of Methyle, . . . . .	$C_2H_3O$ , or MeO
Chloride of Methyle, . . . . .	$C_2H_3, Cl$ or MeCl
Iodide of Methyle, . . . . .	$C_2H_3, I$ or MeI
Hydrated Oxide of Methyle, Wood Spirit, Pyroxylic Spirit, or Methylic Alcohol, . . . . .	
	$C_2H_3O + HO$ or MeO + HO
Sulphate of Oxide of Methyle, . . . . .	$C_2H_3O + SO_3$ or MeO + $SO_3$
Nitrates, Oxalates, &c., &c.	
Salicylate of Oxide of Methyle, or } Oil of Gaultheria procumbens, }	$C_2H_3O + C_{14}H_3O_4 + O = C_{16}H_3O_5$
&c. &c.	

Methyle has never been isolated; but its constitution, like that of ethyle, is inferred to be  $C_2H_3$ .

*Hydrated Oxide of Methyle; Wood Spirit; Pyroxilic Spirit, or Methylic Alcohol.*— $C_2H_3O + HO$ , or MeO + HO. Crude wood vinegar contains about  $\frac{1}{100}$  part of this substance. The whole is redistilled, the product neutralized by lime, and the acid thus removed; the spirit thus obtained is again distilled with chloride of calcium, to render it anhydrous. It is a colourless, thin liquid, with a peculiar odour, and a burning, disagreeable taste. It boils at  $152^\circ F.$ ; has a density of  $\cdot 798$  at  $60^\circ$ . It is miscible with water in all proportions, and dissolves resins and volatile oils like ordinary alcohol.

*Oxide of Methyle; Methylic Ether.*— $C_2H_3O$ , or MeO. If we add 4 parts of sulphuric acid to 1 part of methylic alcohol, in a retort, and apply heat, a gaseous body, not condensable, will distil over, which is pure methylic ether. It is colourless, has an ethereal odour, and is inflammable. Water absorbs 33 times its volume. It is soluble in alcohol,

sulphuric acid, and wood spirit. This body unites with acids, and forms true salts.

*Chloride of Methyle.*— $C_2H_3Cl$ , or  $MeCl$ . This is prepared by distilling a mixture of common salt, wood spirit, and sulphuric acid. The sulphuric acid takes the soda which has resulted from the union of the sodium with the oxygen of the methylic alcohol, thus freeing methyle; and forms sulphate of soda, which remains in solution. The chlorine and methyle being both freed, unite, and form the chloride of methyle. By symbols,  $C_2H_3O$ ,  $HO$ ,  $NaCl$ , and  $SO_3$ , give  $NaO$ ,  $SO_3 + HO$ , and  $C_2H_3Cl$ .

This is also a gaseous body, colourless, with a peculiar odour, a sweet taste, and inflammable.

The Iodide, Bromide, Cyanide, &c., are obtained in the same way.

*Sulphate of Oxide of Methyle.*— $H_2C_3O + SO_3$ , or  $MeO, SO_3$ . This is a true sulphuric ether, which has no analogue in the ethyle series.

It is made by adding a large excess of acid to methylic alcohol, and heating. Oxide of methyle is first developed; which then unites with sulphuric acid, and forms a neutral sulphate. It is a heavy, oleaginous-looking liquid, with an alliaceous odour; neutral to test paper, and insoluble in water. Heated with formiate of soda, it yields, by double decomposition, formiate of methyle, and sulphate of soda.

*Nitrate of Oxide of Methyle.*— $H_2C_3O + NO_5$ , or  $MeO, NO_5$ . This is prepared by adding in a retort and heating, wood spirit, nitrate of potassa, and sulphuric acid. It is liquid, heavier than water, boils at  $180^\circ$ ; but when heated to  $300^\circ$  it explodes with intense violence.

*Salicylate of Oxide of Methyle.*— $C_2H_3O + C_{14}H_5O_4 + O = C_{16}H_8O_6$ . This is obtained in the laboratory by distilling salicine and wood spirit. It is identical with the oil of Gaultheria procumbens, or Partridge-berry.



## PRODUCTS OF THE OXIDATION OF METHYLIC ALCOHOL.

## FORMYLE.



It has been seen that when alcohol is exposed to the action of an oxidizing agent, it is converted into acetic acid; so when wood spirit is exposed to the action of the same agents, as spongy platinum, ferments, &c., it is also converted into a similar body, called *formic acid*. This is due to the dehydrogenation of the wood spirit in the present case, as it was in the former, which gives origin to a new series, resembling the acetylene group, the compound radical of which is formyle. The oxides of this radical are acids.

## FORMYLE SERIES.

Formyle,	.	.	.	.	.	.	$\text{C}_2\text{H}$
Formic Acid,	.	.	.	.	.	.	$\text{C}_2\text{H}_2\text{O}_3 + \text{HO}$
Chloroform,	.	.	.	.	.	.	$\text{C}_2\text{H}_2\text{Cl}_2 + \text{HO}$
Bromoform,							
Iodoform, &c.							

There are no compounds of formyle as yet discovered corresponding to aldehyde and aldehydic acid.

*Formic Acid*.— $\text{C}_2\text{H}_2\text{O}_3 + \text{HO}$ . Wood spirit by oxidation yields formic acid, as alcohol by oxidation yields acetic acid. This acid has been discovered in the red ant, and hence the term formic has been applied to it. It is readily made by exposing wood spirit to the action of platinum sponge, or yeast, in the open air. By presenting chromic acid in its nascent condition to methylic alcohol, we can also obtain formic acid. The best way to accomplish this is to add dilute sulphuric acid to a mixture of methylic alcohol and bichromate of potassa. The sulphuric acid takes the potassa and frees the chromic acid, which now imparts its oxygen to

the wood spirit, removes its hydrogen, and forms formyle, which it then oxidizes, forming formic acid; the chromic acid is converted into a sesquioxide of chromium. Formic acid is chemically a hydrated teroxide of formyle; it is a clear, colourless liquid, fumes in the air, has a penetrating odour, boils at  $212^{\circ}$ , and crystallizes at  $32^{\circ}$ .

Concentrated, it is extremely corrosive; it reddens litmus, and decomposes alkaline carbonates. It is obtained from red ants by merely macerating them in water.

It is tested from acetic acid by dissolving the oxide of silver, and then reducing it to the metallic condition by heat.

*Chloroform.*— $C_3HCl_3 + HO$ . This is made by the action of chloride of lime on alcohol, wood spirit, or acetone. It is a case of simple substitution; heat is necessary for the process. The hydrogen is removed by the chlorine, the oxygen by the calcium, carbonic acid is also formed, and a hydrated terchloride of formyle is obtained. This is a thin, colourless liquid, with an agreeable ethereal odour, and remarkable for its very small drop. Its sp. gr. is 1.49, boils at  $141^{\circ}$ , and is not inflammable. It is insoluble in water, but soluble in alcohol and ether; it has been much used for its anæsthetic properties.

Bromoform, Iodoform, &c., are merely other varieties of the same class.

#### AMYLE AND ITS COMPOUNDS.

In manufacturing whiskey from potatoes, it was found that the product contained an acrid volatile substance, which, on being investigated, presented properties strikingly analogous to common alcohol and methylic alcohol. To this the name of amylic alcohol was given, because it was obtained from amylaceous materials, and to its base, which is another compound salt radical, the name of amyle was given.

AMYLE SERIES.

Symbol (Ayl.)

Amyle, . . . . .	$C_{10}H_{11}$
Amylic Ether (unknown), . . . . .	$C_{10}H_{11}O$
Amylic Alcohol (Potato Oil), . . . . .	$C_{10}H_{11}O + HO$
Chlorides, Bromides, Iodides, &c.	
Amilen, . . . . .	$C_{10}H_{10}$
Valerianic Acid, . . . . .	$C_{10}H_9O_3 + 2HO$

*Amyle.*— $C_{10}H_{11}$ . Has not been isolated.

*Oxide of Amyle, or Amylic Ether.*—Has not been discovered.

*Amylic Alcohol ; Hydrated Oxide of Amyle.*— $C_{10}H_{11}O + HO$ , or  $AylO + HO$ . This is obtained by distilling potatoes. It is thin, mobile, has a powerful odour, and a burning taste ; its sp. gr. .818, and boiling point  $269^{\circ} F$ .

The *chlorides*, &c., are of no consequence. They are prepared by distilling the chloride, bromide, or iodide of sodium, with potato oil and sulphuric acid in a retort. Sulphate of soda remains in the retort, while a chloride, an iodide, or a bromide of amyle distils over.

*Amilen.*— $C_{10}H_{10}$ . By distilling amylic alcohol with dry phosphoric acid, a volatile, colourless, oily liquid is produced ; lighter than water, and isomeric with olefiant gas. It contains no oxygen, as seen by the formula, and is called amilen.

ACTION OF OXYGEN ON AMYLIC ALCOHOL.

*Valerianic Acid.*— $C_{10}H_9O_3 + 2HO$ . By dehydrogenating amylic alcohol in the same way that common and methylic alcohol were treated, viz., by spongy platinum, or a ferment, or by presenting a body yielding oxygen, as chromic acid, a new acid is obtained, called valerianic acid, analogous to acetic and formic acids. It is the hydrated teroxide of a new compound acid radical, having  $C_{10}H_9$ , but which has as yet

received no name. The body thus produced is found to be the same as an oily acid distilled from the root of the *Valeriana officinalis*.

Prepared artificially, it is a thin, colourless oil, with a sharp acid taste. It reddens litmus, and burns with a strong light.

This acid may be obtained also from sugar of milk. When a ferment is presented to this, it is converted into lactic acid and mannite; but if the temperature be suddenly raised to a high point, and kept at that point, the lactine is converted into butyric and valerianic acids.

### SECTION III.

#### SUBSTANCES DIFFERING FROM THE PRECEDING, BUT HAVING COMPOUND RADICALS.

##### BENZOYLE.

THE different varieties of the peach, the plum, and the almond, give an oily body by distillation, called the oil of bitter almonds. This oil is supposed to be the hydruret of a base called benzoyle, which has not yet been isolated.

##### BENZOYLE SERIES.

Benzoyle, symbol Bz . . . . .	$C_{14}H_5O_2$
Hydruret of Benzoyle; Oil of Bitter Almonds,	$C_{14}H_5O_2 + H$
Oxide of Benzoyle; Benzoic Acid, . . . .	$C_{14}H_5O_2 + O$
Chloride, Bromide, Iodide, &c.	

*Hydruret of Benzoyle; Oil of Bitter Almonds.*— $BzH$  or  $C_{14}H_5O_2 + H$ . The peach, plum, or almond, do not contain

the oil of bitter almonds, before distillation. The almond itself only yields on expression a bland body, called the oil of sweet almonds, analogous to olive oil. During the process of distillation, however, a reaction takes place between *amygdalin* and *emulsin*, two bodies found in the above-mentioned substances, which results in the production of oil of bitter almonds. Water is necessary to the reaction.

The process is called the amygdalic fermentation: *emulsin*, or *synaptase*, as it is called, is the fermenting body.

*Amygdalin* has been obtained separate by boiling the paste of bitter almonds in alcohol; this coagulates the *emulsin* and dissolves out the *amygdalin*. It is obtained from its alcoholic solution in white crystalline plates. It is composed of  $C_{40}H_{27}O_{23}N$ . *Synaptase*, or *emulsin*, has never been determined; it is supposed to be an albuminous body.

The crude oil of bitter almonds, as it is made, contains a good deal of hydrocyanic acid, from which it must be purified. When pure, it is thin, colourless, very refractive, heavier than water, in which it is to a slight extent soluble, and boils at  $356^{\circ} F$ .

Exposed to the air, it absorbs oxygen, and is converted into benzoic acid.

It is uncertain whether pure oil of bitter almonds is poisonous or not.

*Oxide of Benzoyle; Benzoic Acid.*— $C_{14}H_5O + O$  or  $BzO$ . This is the result of the oxidation of oil of bitter almonds. It is also obtained from the balsams by merely subliming them; the benzoic acid volatilizes, and is made to condense in a suitable arrangement.

It is in light, feathery crystals, with a fragrant odour, due to impurities. It is soluble in cold water, but more in boiling water.

The chlorides, iodides, bromides, &c., are all obtained in the usual way.

## CINNAMYLE.

The oil of cinnamon is not a fat body. It is very analogous to the oil of bitter almonds, and it is a hydruret of a supposed compound radical, called cinnamyle.

## CINNAMYLE SERIES.

Cinnamyle, symbol Ci, . . . . .	$C_{18}H_7O_2$
Hydruret of Cinnamyle; Oil of Cinnamon, . . . . .	$C_{13}H_7O_2 + H$
Oxide of Cinnamyle; Cinnamic Acid, . . . . .	$C_{18}H_7O_2 + O$
Chlorides, Iodide, &c.	

*Hydruret of Cinnamyle; Oil of Cinnamon.*— $C_{18}H_7O_2 + H$ , or  $CiH$ . This is obtained by distilling bruised cinnamon from water. It is heavier than, and slightly soluble in water.

*Cinnamic Acid.*— $C_{18}H_7O_2 + O$ , or  $CiO$ . This is the result of the oxidation of oil of cinnamon; it is also found in all the balsams. Benzoic, or cinnamic acid, or both, are necessary to the constitution of a balsam.

The chloride, iodide, &c., are got in the usual way.

## SALICYLE.

All the varieties of the willow, and many poplars, contain in their inner bark a bitter principle analogous to quinia, called *salicine*. This is obtained in colourless, silky needles; intensely bitter, and soluble in 6 parts cold water. It is coloured red by sulphuric acid. Its formula is  $C_{21}H_{14}O_{11}$ .

When salicine is treated with sulphuric acid and bichromate of potassa, the salicine is oxidized by the chromic acid, which is freed by the potassa uniting with the sulphuric acid, and the salicine is converted into several bodies, one of which is a volatile oil, identical with that obtained from the *Spiræa ulmaria*, or *Pride of the Meadow*. This oil is supposed to be the hydruret of a compound radical, called salicyle.



## SALICYLE SERIES.

Salicyle, symbol Sl,	$C_{14}H_5O_4$
Hydruret of Salicyle; Oil of <i>Spiræa ulmaria</i> ,	$C_{14}H_5O_4 + H$
Iodide, Bromide, &c.	
Salicylic Acid,	$C_{14}H_5O_4 + O$
Salicylate of Methyle, or Oil of <i>Gaultheria</i>	
procumbens,	$C_2H_3O + C_{14}H_5O_5$

*Hydruret of Salicyle; Oil of Spiræa Ulmaria.*— $C_{14}H_5O_4 + H$ , or  $SlH$ . This is prepared artificially by distilling salicine and water with a large excess of sulphuric acid. It is thin, colourless, has a sp. gr. of 1.17, and boils at  $385^\circ F$ . It is acted on by chlorine, bromine, &c., producing chlorides, bromides, &c.

*Salicylic Acid.*— $C_{14}H_5O_4 + O + HO$ , or  $SlO + HO$ . This is prepared by treating the hydruret with caustic potassa. It is obtained in crystals resembling benzoic acid; soluble in alcohol and ether, and readily sublimed. This acid combines not only with metallic oxides, to form salts, but also with the oxides of compound radicals.

*Salicylate of Methyle; Oil of Gaultheria Procumbens.*— $C_2H_3O + C_{14}H_5O_5$ , or  $SlOC_2H_3O$ . This is prepared by distilling salicine and wood spirit.

## SECTION IV.

## COMPOUND RADICALS CONTAINING NITROGEN.

## CYANOGEN AND AMIDOGEN.

*Cyanogen.*— $C_2N$ . This is chemically a bicarburet of nitrogen; it and kakodyle are the only radicals that have been

isolated. It is a compound of organic origin, and is obtained by heating any organic nitrogenized body with a small quantity of an alkali. A cyanide of the alkali is thus obtained. Its constitution, and most of its important compounds, have already been treated of, in Inorganic Chemistry.

*Amidogen*.— $\text{NH}_2$ . This is a hypothetical body, supposed to exist in ammonia.

Ammonia is the product of an organic, nitrogenized body, and is obtained by heating such a body with a large excess of an alkali. This body and its compounds have also been treated of.

The amidogen series is as follows :

Amidogen, symbol Ad,	.	.	$\text{NH}_2$
Ammonia, . . . .	.	.	$\text{NH}_3$ , or $\text{Ad} + \text{H}$
Ammonium, . . . .	.	.	$\text{NH}_4$ , or $\text{Ad} + 2\text{H}$

## SECTION V.

### ORGANIC OR VEGETABLE ACIDS.

THESE bodies constitute a very extensive and important group of bodies in nature ; indeed, there is scarcely a plant that has not, at some time or other, a specific acid developed. They are nearly all of the type of phosphoric acid ; that is, polybasic.

They may be divided, generally, into those which pre-exist as such, and those which are the results of the action of reagents.

Those resulting from the action of heat on original acids are called pyrogenous acids.

## TABLE OF ACIDS.

Acetic Acid, . . .  $C_4H_3O_3 + HO$

Tartaric Acid, . . .  $C_8H_4O_{10} + 2HO$

This, by the action of heat, yields

Pyruvic Acid, . . .  $C_5H_3O_3$ , and carbonic acid and water.

Racemic Acid, . . .  $C_8H_4O_{10} + 2HO$

Citric Acid, . . .  $C_{12}H_8O_{11} + 3HO$

This, by the action of heat, yields 3 equivalents of

Aconitic Acid, . . .  $C_4HO_3 + HO$ , and 2 equiv. of water.

Malic Acid, . . .  $C_8H_4O_8 + 3HO$

This, by heat, yields

Maleic Acid, . . .  $C_8H_2O_6 + 3HO$ , and 2 equiv. of water.

Tannic Acid, . . .  $C_{18}H_5O_9 + 3HO$

Gallic Acid, . . .  $C_7HO_3 + 2HO$

Kinic Acid, . . .  $C_7H_4O_2 + 2HO$

Oxalic Acid, . . .  $C_2O_3 + HO$ , or  $CO_2 + CO + HO$

*Acetic Acid*.— $C_4H_3O_3 + HO$ . This acid is that which is most common to all plants. We have already seen it developed by the oxidation of alcohol; and as this is a product of sugar, and this again of starch, it is but fair to infer that in plants the vegetable diastase of the plants converts the starch into acetic acid, conducting it through the intermediate stages. It exists generally, in plants, in combination with potassa or soda.

*Tartaric Acid*.— $C_8H_4O_{10} + 2HO$ . This acid occurs as a salt of lime or potassa in the grape, tamarind, and other fruits. That of commerce is got from *argol*, which is the acid tartrate of potassa deposited during the fermentation of wine. This argol is purified by boiling, &c., and then constitutes *cream of tartar*. A solution of this is now effected, lime is added, and an insoluble tartrate of lime is thrown down; sulphuric acid is now cautiously added, which removes the lime, and sets free the acid, which is now crystallized from its solution by evaporation.

The crystals are transparent, rhomboidal, soluble in water

and alcohol, redden litmus paper, and have a pure acid taste. It is a bibasic acid; its two equivalents of water acting as bases, may be substituted by any other bases.

#### SALTS OF TARTARIC ACID.

*Acid Tartrate of Potassa; Cream of Tartar.*— $\text{KO}$ ,  $\text{HO}$ ,  $\text{C}_8\text{H}_4\text{O}_{10}$ . This has already been noticed above in the preparation of the acid. It is soluble in 60 parts of cold water, and much less boiling water. Heated in a close vessel it is converted into black flux, which is a mixture of carbon and carbonate of potassa.

*Tartrate of Potassa; Soluble Tartar.*— $2\text{KO}$ ,  $\text{C}_8\text{H}_4\text{O}_{10}$ . This is prepared by adding carbonate of potassa to a solution of cream of tartar until effervescence ceases. It is very soluble.

*Tartrate of Potassa and Soda; Rochelle Salt.*— $\text{KO}$ ,  $\text{NaO}$ ,  $\text{C}_8\text{H}_4\text{O}_{10} + 10\text{HO}$ . This is prepared by neutralizing a hot solution of cream of tartar with carbonate of soda, and evaporating.

There are many other salts bearing the same general constitution as those described.

*Pyrumic Acid.*— $\text{C}_6\text{H}_3\text{O}_5$ . When tartaric acid is heated it is decomposed; it loses carbonic acid and water, and is converted into pyrumic acid. This acid forms salts, an ether, and has the odour of acetic acid.

*Racemic Acid.*— $\text{C}_8\text{H}_4\text{O}_{10} + 2\text{HO}$ . This acid, which has the same formula as tartaric, hence called paratartaric acid, is found in the grapes cultivated in the Upper Rhine districts. It differs from tartaric, by not forming a compound similar to tartrate of antimony and potassa (tartar emetic).

*Citric Acid.*— $\text{C}_{12}\text{H}_5\text{O}_{11} + 3\text{HO}$ . This acid is found in the juices of the lemon, lime, currant, gooseberry, and many other fruits. It is got by adding carbonate of lime to the

juice of the lemon, having first heated it to coagulate the pectic acid. Sulphuric acid is then added, which removes the lime, and leaves the citric acid in solution, which by evaporation yields rhombic prisms. It is polybasic, forming mono, bi, and tribasic salts. It is tested from tartaric acid by forming a soluble citrate of potassa, while the acid tartrate is comparatively insoluble.

*Aconitic Acid.*— $C_4H_3O_3 + HO$ . When citric acid is heated, it divides into 3 equivalents of an acid identical with that found in the *Aconitum napellus*, and two equivalents of water.

*Malic Acid.*— $C_3H_4O_3 + 3HO$ . This acid is found in the ripe apple and pear, and in the garden rhubarb, in combination with citric acid. It is obtained by first forming a malate of lead, and then removing the lead by sulphuretted hydrogen. Crystals are obtained soluble in water and alcohol; but the aqueous solution soon spoils. It is bibasic. By heat it is converted into *maleic* and *fumaric* acids.

*Tannic Acid.*— $C_{13}H_5O_9 + 3HO$ . This acid, in connexion with gallic, constitutes the astringent principle of a great variety of plants. It is obtained most abundantly from nut-galls, excrescences resulting from the puncture of an insect in the bark of the *Quercus infectoria*. Whether the acid exists as such, and with what base, or whether it is the result of the reactions of our means used to obtain it, are equally unknown. It is got by treating the powdered galls with ether containing a little water, in a displacement apparatus; a liquid percolates through, which divides itself into two strata in the receiver; the lower stratum is a strong solution of tannic acid in water, while the upper is an ethereal solution of gallic acid, colouring matter, &c. The dry acid obtained by evaporation, is yellowish, porous, not crystallizable, soluble in water and alcohol, and has a pure astringent taste. It is tribasic, and forms insoluble salts with the earths, metals proper, gelatin, vegetable alkalies, &c., &c.

The test for tannic acid is a sesquisalt of iron, with which it gives a blue-black precipitate, which is the basis of writing ink. The tannate of the protoxide is colourless. With gelatin, tannic acid gives a precipitate, the tannate of gelatin possessing great insolubility and indestructibility; this is leather.

*Kinic Acid*.— $C_7H_4O_2 + 2HO$ . Kino, catechu, &c., contain an acid resembling tannic, but which yields a green-black precipitate with the sesquisalts of iron.

When tannic acid in solution is exposed, it is decomposed, and an organic growth, a cryptogamous vegetation, takes place on it, called mould. By oxidation it yields gallic acid.

*Gallic Acid*.— $C_7HO_3 + 2HO$ . This is prepared by exposing a solution of tannic acid to the air and allowing it to mould; filter, and evaporate till the crystals form.

It forms feathery crystals, soluble in 100 parts cold and 3 parts boiling water; has an acid astringent taste; does not precipitate gelatin, and forms no precipitate with a protosalt of iron.

*Oxalic Acid*.— $C_2O_3$ ,  $HO$  or  $CO + CO_3$ ,  $HO$ . This acid, which we have already seen obtained by the action of nitric acid on sugar, is also got from the sorrel, rhubarb, and many other plants. It occurs in combination with lime or potassa, from which it is readily separated by sulphuric acid. It crystallizes in rhombic prisms, containing three equivalents of water. It is soluble in water, is intensely sour, has a strong acid reaction, and is very poisonous. The antidote of oxalic acid is lime, with which it forms a compound very insoluble in water, but soluble in nitric and other acids. It contains the elements of carbonic acid and carbonic oxide, into which it is decomposed by the action of a strong acid.

Oxalic acid differs from the other vegetable acids by being monobasic, and it will also unite in more than one proportion to a single equivalent of base.



## SALTS OF OXALIC ACID.

*Neutral Oxalate of Potassa.*— $\text{KO}, \text{C}_2\text{O}_3, \text{HO}$ . This is prepared by neutralizing oxalic acid by carbonate of potassa.

*Binoxalate of Potassa.*— $\text{KO}, 2(\text{C}_2\text{O}_3) + 3\text{HO}$ . This is called salt of sorrel; it exists in the *Oxalis acetosella*, or sorrel, and in garden rhubarb.

*Quadroxalate of Potassa.*— $\text{KO}, 4(\text{C}_3\text{O}_3) + 7\text{HO}$ . This is prepared by neutralizing one part of oxalic acid with potassa, and then adding three parts more of acid.

*Oxalate of Ammonia.*— $\text{NH}_4\text{O}, \text{C}_2\text{O}_3 + \text{HO}$ . This is prepared by neutralizing oxalic acid with carbonate of ammonia; it crystallizes from the solution in colourless rhombic prisms. It occurs sometimes as the mulberry calculus in the kidneys and bladder. It is used as a test for lime. When heated in a retort it is decomposed into many products, one of which is oxamide, a peculiar grayish-white body; also obtained by adding ammonia to oxalic ether. Its formula is  $\text{C}_2\text{H}_2\text{NO}_2$ , or  $\text{C}_2\text{O}_2\text{NH}_2$ .

## SECTION VI.

## ORGANIC SALT BASES.

## VEGETO-ALKALIES.

THESE bodies form a very important group in nature. They all contain nitrogen, are analogous to ammonia, and are found always associated with an acid. They are very complex, have high combining numbers, unite with oxy-acids forming salts, and also with the hydracids or halogen bodies,

forming compounds like the chloride of ammonium. They are sparingly soluble in water, but are soluble in hot alcohol, from which they crystallize on cooling.

TABLE OF SOME VEGETO-ALKALIES.

Morphia,	. . . . .	$C_{35}H_{20}NO_6$
Codeia, .	. . . . .	$C_{35}H_{20}NO_5$
Thebaia, }	composition not known.	
Narceia, }		
Narcotina,	. . . . .	$C_{48}H_{24}NO_1$
Coneia,	. . . . .	$C_{16}H_1N$
Nicotia,	. . . . .	$C_{10}H_8N$
Quinia,	. . . . .	$C_{20}H_{12}NO_2$
Cinchonia,	. . . . .	$C_{20}H_{12}NO$
Aricina,	. . . . .	$C_{29}H_{17}NO_2$
Strychnia,	. . . . .	$C_{44}H_{22}O$
Brucia,	. . . . .	$C_{44}H_{22}N_2O_7$
Veratria,	. . . . .	$C_{34}H_{22}NO_6$
Aconitina.		
Caffein, }	. . . . .	$C_8H_8N_2O_2$
Thein, }		
Theobromin,	. . . . .	$C_7H_8N_2O_2$

*Morphia*.— $C_{35}H_{20}NO_6$ . Morphia is found associated with acids, other alkalies, gum, resin, caoutchouc, &c., in the juices of the papaveraceæ, and most abundantly in the *Papaver somniferum*, or poppy. It is obtained from opium, which is the inspissated juice of the poppy head, by first making an infusion. The morphia which exists, combined with sulphuric and meconic acids, is dissolved out along with a meconate of narcotina. A solution of ammonia is now added to this, and a precipitate falls, consisting principally of morphia and narcotina, while the meconate and sulphate of ammonia remain in solution. It is purified and decolorized by boiling in alcohol and filtering through animal charcoal; but it contains narcotina, which

is separated by ether, it being soluble in that menstruum, while the morphia is insoluble in it.

Morphia is also obtained by treating the infusion of opium with chloride of calcium; this gives a meconate of lime and a chloride of morphia, which latter, treated with an alkali, precipitates the morphia.

It occurs when crystallized from alcohol in very small transparent, colourless, prismatic crystals, requiring 1000 times their weight of water to dissolve them, with a slightly bitter taste and an alkaline reaction. Heated, they melt, and take fire.

Morphia gives a blue precipitate with the persalts of iron, and forms a yellowish-red compound with nitric acid, analogous to carboazotic acid.

The bichloride of platinum, added to a solution of a salt of morphia, or any organic salt, gives a yellow precipitate of the bichloride of platinum and the alkaloid, precisely like the bichloride of platinum and ammonium, because the alkaloids are very analogous to ammonia.

It forms a sulphate, an acetate, a phosphate, a chloride, &c., &c.

*Codeia*.— $C_{35}H_{20}NO_5$ . The chloride of morphia, prepared by adding the chloride of calcium to an infusion of opium, contains codeia, from which it is obtained by the addition of ammonia. It crystallizes in octohedrons.

*Thebaia* and *Narceia* are little known.

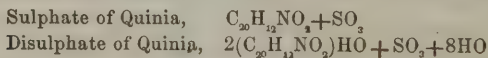
*Narcotina*.— $C_{43}H_{24}NO_{15}$ . This was supposed to be the stimulant principle of opium, and denarcotized opium was prepared to obviate its stimulant properties. It is obtained by treating with ether the precipitate resulting from the addition of ammonia to an infusion of opium. The narcotina is dissolved out by the ether, and this solution evaporated, leaves the narcotina in small colourless prisms, insoluble in water. It is a feeble base, and has no alkaline reaction.

*Coneia*.— $C_{16}H_{16}N$ . Coneia is the active principle of *Conium maculatum*, or *hemlock*. It is a volatile, oily liquid, with a strong alkaline reaction, forming crystalline salts. It is very poisonous.

*Nicotia*.— $C_{10}H_8N$ . This is obtained from the *Nicotiana tabacum*, or tobacco; it possesses the same general properties with coneia.

*Quinia*.— $C_{20}H_{12}NO_2$ . This is obtained from the different varieties of cinchona bark, most abundantly from the yellow (or calisaya) bark. It exists in combination with sulphuric and kinic acids; and is got by digesting the ground bark in water, acidulated with sulphuric acid, in a water bath, at  $212^\circ$  F. The water is thus enabled to dissolve out the organic salts. Lime is now gradually added, and quinia and cinchonia (another alkaloid) are precipitated, along with sulphate and kinate of lime, and some colouring matter. This is now digested in alcohol, which dissolves out the alkaloids, sulphuric acid is added until the solution becomes neutral, and sulphate of quinia and cinchonia are thus obtained. These are then dissolved in water at  $212^\circ$ , filtered through animal charcoal, and set aside to crystallize. The sulphate of quinia being the least soluble, crystallizes out first, while the sulphate of cinchonia remains in the mother waters. Quinia is obtained from the sulphate by the addition of any strong alkali. It crystallizes in small, transparent, four-sided prisms, slightly soluble in water, and with an intensely bitter taste.

Quinia forms two sulphates, viz., the neuter and disulphate. The former is very soluble, while the latter is comparatively insoluble. It is this last which is used, in medicine.



*Cinchonia*.— $C_{20}H_{12}NO$ . This is obtained by the process detailed for quinia, which it resembles very much. It is, however, less soluble in water, and has much less bitterness.

*Aricina*.— $C_{20}H_{12}NO_3$ . This is obtained from *Arica bark*, in the same manner that quinia and cinchonia are prepared. It resembles cinchonia. It will be seen by the formulas that quinia contains one equivalent more of oxygen than cinchonia, and aricina one more than quinia; and lately, quinia, it is said, has been produced by the oxidation of cinchonia.

*Strychnia*.— $C_{44}H_{23}N_2O_8$ . This alkaloid is contained in the fruit of the *strychnos*, *nux vomica*, and in the bean of St. Ignatius. This and another alkali, called *brucia*, exist in combination with *igasuric* acid. It is obtained by boiling the crushed seeds in water acidulated with sulphuric acid, and then adding lime to precipitate it. The precipitate, which contains brucia, is then treated in hot alcohol and filtered: the brucia is soluble in the cold alcohol, while the strychnia crystallizes out. It has a bitter taste, is slightly soluble in water, and is a fearful poison. It forms salts.

*Brucia*.— $C_{44}H_{25}N_2O_7$ . The process for getting it is seen above. It differs from strychnia by being soluble in cold alcohol.

*Veratria*.— $C_{34}H_{22}NO_6$ . This is got from the seeds of the *Veratrum sabadilla*. It is a white powder, very poisonous, soluble in hot alcohol, and has an alkaline reaction.

*Aconitina* is the product of the root of the *Aconitum napellus*, or wolfsbane.

Its constitution is not known.

*Caffein* or *Thein*.— $C_8H_5N_2O_3$ . This is found in tea, coffee, and matte. It is prepared by treating a decoction of tea, coffee, or matte with subacetate of lead, then removing the lead by sulphuretted hydrogen, and adding ammonia. The caffein crystallizes out in tufts of white silky needles, which have a bitter taste, and sublime without decomposition.

*Theobromin*.— $C_9H_5N_3O_2$ . This substance, analogous to caffein, is found in cocoa. It is got in the same way, and has the same general properties.

## SECTION VII.

## FIXED OILS AND FATS.

THE fixed oils and fats are entirely distinct, in their constitution and physical properties, from the volatile oils. They are found in plants, in their seeds, fruits, &c., and in animals; but the oils from these sources resemble each other so much, that no distinct classification is made between them.

These oils, when dropped on paper, leave a permanent greasy stain; they absorb oxygen rapidly (sometimes causing spontaneous combustion); and this absorption converts some into hard, solid substances, while others become sour and rancid. The former are called drying, the latter non-drying oils. The drying oils are used in painting; they are linseed, rape, poppy-seed, and walnut oils. The fixed oils, when pure, are tasteless, and inodorous; they are decomposed at  $600^{\circ}$ ; heated in the open air, they burn, giving carbonic acid and water; and, when heated in close vessels, they yield many products, the most important of which is carburetted hydrogen. They are insoluble in, and repel water; are soluble in alcohol to a very slight extent, except castor oil, and are very soluble in ether and the volatile oils.

The consistency of oils and fats varies, owing to the presence, in greater or less quantities, of different bodies into which fats and oils may be resolved.

These may be separated by mere mechanical means, or by low temperature. They are *margarine*, *stearine*, and *oleine*.

Fixed oils and fats, in contact with alkalies, earths, and oxides of metals proper, undergo, at high temperatures, a decomposition, and form, with the alkali, a new compound called soap: the process is termed saponification. Soap is a true



salt; soluble in water and alcohol, which latter renders soap transparent. It is decomposed by the addition of an acid, which, removing the alkali, frees the fat acid with which it was united, and which was separated from the neutral fat by the alkali, during saponification. There is also developed, during saponification, a new body called *glycerine*, which remains in solution, and which acted as a base to the fat acid before saponification. It is thus seen that fats and oils are true salts, composed of several acids united to a base common to all, called *glycerine*, which is susceptible of being removed by any other base having a stronger affinity for the fatty acids than the *glycerine* has.

TABLE OF FATS, FATTY ACIDS, AND BASE.

*Fats.*

Stearine, . . . .	$C_{78}H_{10}O_{83}$
Margarine.	
Oleine.	

*Fatty Acids.*

Stearic Acid, . . . .	$C_{68}H_{66}O_3 + 2HO$
Margaric Acid, . . . .	$C_{68}H_{66}O_3 + 2HO$
Oleic Acid, . . . .	$C_{44}H_{46}O_3 + 2HO$

*Base.*

Glycerine, . . . .	$C_6H_8O_6$ , or $C_6H_7O_5 + HO$
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*Stearine.*—This, the solid constituent of fat, is obtained by melting mutton suet, in which it exists in great excess, in ether, and allowing the whole to cool. The stearine crystallizes out, while the margarine and oleine remain in solution. It is white, friable, insoluble in water and alcohol, but soluble in boiling ether. Its melting point is  $130^{\circ}$  F. Its formula is  $C_{71}H_{70}O_{80}$ . Chemically it is a stearate of *glycerine*.

*Stearic Acid.*— $C_{88}H_{66}O_5 + 2HO$ . When stearine is saponified it yields stearic acid and glycerine. The former may be obtained from the soap formed by the addition of an acid. It is firm, white, solid, fusible at  $160^\circ$ , greasy; soluble in alcohol and ether, but insoluble in water.

• *Margarine.*—This is obtained from the ethereal solution of mutton suet, after the stearine has been removed. It contains oleine, from which it is freed by compression between folds of paper. It resembles stearine, but is more fusible, melting at  $116^\circ$ , and is more soluble in ether. It is a margarate of glycerine.

*Margaric Acid.*— $C_{88}H_{66}O_6 + 2HO$ . This acid resembles stearic very much, but it is more soluble in alcohol; melts at  $140^\circ$ , and has one more equivalent of oxygen. It is obtained by the saponification of margarine. Stearic has been converted into margaric acid by oxidation, by means of nitric acid.

*Oleine.*—This is obtained from the paper by which it has been absorbed in preparing margarine by compression under water. It is also got by filtering the fixed oils at the temperature of freezing. It resembles oil in appearance, has no colour when pure; congeals at  $20^\circ F.$ , has little odour, is soluble in boiling alcohol and ether, and is insoluble in water. It is an oleate of glycerine.

*Oleic Acid.*— $C_{44}H_{40}O_4 + 2HO$ . This acid, which is got also by the saponification of oleine, resembles the latter very much. It is a colourless liquid, lighter than water; has an acid reaction, as all the rest have, and is soluble in alcohol in all proportions.

*Glycerine.*— $C_6H_8O_6$ , or  $C_6H_7O_5 + HO$ . This is the base common to all the fats. It is obtained best by forming an insoluble soap with olive oil, oxide of lead and water (the latter being necessary to all saponification). The oleo-margarate of the oxide of lead (lead plaster) is formed, and

precipitated, while the glycerine remains in solution. It is obtained from the solution by evaporation in vacuo. When pure, it is a colourless, viscid liquid, of specific gravity 1.27, with a sweet taste and soluble in water. Nitric acid converts it into oxalic acid.

Glycerine is now said to be the hydrated oxide of a hypothetical base, called *glyceryle*. Thus,

Glyceryle,	. . . . .	$C_6H_7$
Oxide of glyceryle,	. . . . .	$C_6H_7O_5$
Glycerine; the hydrated oxide of glyceryle,	. . . . .	$C_6H_7O_5 + HO$

It has also been said that the real base, as it exists in the fat, is *lyppyle*; the formula for which is  $C_3H_4$ .

*Acroline*.— $C_6H_4O_2$ . By destructive distillation, the fats yield, among other bodies, a gas, which when condensed forms a poisonous volatile liquid, called *acroline*.

There are many other fats and oils beside those mentioned, having the same general constitution, as *palm oil*, *cocoa-nut oil*, the solid fat from the nutmeg, butter, &c. This last has, in addition to the common fats, three volatile fatty acids, viz., *butyric*, *capric*, and *caproic* acids.

*Wax* is another substance analogous to the fats. It is composed of two bodies: the first, *cerine*, is soluble in alcohol and water, and is saponifiable; the second, *myricene*, is insoluble in water and alcohol, and is non-saponifiable.

*Spermaceti* is found in the head of the sperm-whale. It melts at  $120^\circ$ , is soluble in ether and boiling alcohol, and is saponifiable.

#### NON-SAPONIFIABLE FATS.

*Cholesterine*.—This substance exists in very small quantities in the bile ( $\frac{1}{10}$  of 1 per cent.), forms gall-stones, is found, too, in the blood, nervous tissues, tubercle, dropsical fluids,

&c. It is tasteless, inodorous, soluble in ether and boiling alcohol. It is  $C_{36}H_{32}O$ .

*Serolin* is found in the serum of the blood.

## SECTION VIII.

### VOLATILE OILS.

VOLATILE oils are of vegetable origin, and are exceedingly numerous; indeed there is not a tree or plant in the universe, that does not, at some time or other, emit an odour, and that odour is due to a volatile oil. These oils will not grease; they leave no stain, and are, therefore, not fats at all, neither should they be classed among them. They are converted into vapour at slight elevations of temperature; their boiling point is generally greater than  $212^{\circ}$ , and they can, therefore, be distilled over water. When pure, they are colourless; their odour is powerful, and their taste pungent and burning. They resist saponification, as would be inferred by their not being fats; but when exposed to the air, they become oxidized, and are converted into resins; they also deposit, on standing, a solid crystalline matter called *stearoptin*.

They are divided into carbo-hydrogens, and those containing oxygen, and those containing sulphur and nitrogen.

TABLE OF SOME VOLATILE OILS WHICH ARE PURE CARBO-HYDROGENS.

Oil of Lemons,	.	.	.	.	.	.	$C_{10}H_8$
" Copaiba,	.	.	.	.	.	.	$C_{10}H_8$
" Calamus,	.	.	.	.	.	.	$C_{10}H_8$
" Turpentine,	.	.	.	.	.	.	$C_{20}H_{16}$
" Savin,	.	.	.	.	.	.	$C_{20}H_{16}$

Oil of Cloves, . . . . .	$C_{20}H_{26}$
" Black Pepper, &c. . . . .	$C_{20}H_{26}$
" Cubebs, . . . . .	$C_{18}H_{16}$
" Juniper, . . . . .	$C_{18}H_{16}$
" Roses, . . . . .	CH
&c., &c.	

## OILS CONTAINING CARBON, HYDROGEN, AND OXYGEN.

Oil of Pennyroyal, . . . . .	$C_{10}H_8O$
" Rosemary, . . . . .	$C_{10}H_8+2HO$
" Bergamot, . . . . .	$C_{10}H_8+2HO$
" Peppermint, . . . . .	$C_{20}H_{20}+2HO$
" Camphor, . . . . .	$C_{20}H_{16}O$
Artificial Camphor, . . . . .	$C_{20}H_{22}Cl_4$

## SULPHURIZED OILS.

Oil of Black Mustard, . . . . .	$C_{22}H_{20}N_4S_5O_8$
" " Onions, . . . . .	} Contain sulphur and ni- trogen, but have not been analyzed.
" " Assafœtida, . . . . .	
" " Horseradish, . . . . .	

The pure carbo-hydrogen oils possess a wonderful similarity, and the same description would almost answer for all.

*Oil of Lemons.*— $C_{10}H_8$ . This is got from the rind, in which it is contained in little cells; it is got by expression.

The oils of *copaiba* and *calamus* are the same in constitution; they are got by distillation.

*Oil of Turpentine.*— $C_{20}H_{16}$ . This is obtained by distilling the juice (called crude turpentine) which exudes from the pines and firs. The solid left is *rosin*. The oil is thin, colourless, with a terebinthinate odour, a density of .865, and a boiling point of  $312^\circ$ . It is soluble in alcohol and ether. It unites with chlorine, forming a chloride of camphine, called artificial camphor. Pure camphor is oxide of camphine. The

oils of savin, cloves, black pepper, &c., &c., have chemically the same constitution as the above.

*Oil of Roses.*—CH. This is just the same in constitution with the fetid, stinking gas, carburetted hydrogen. It is said to be its allotropic condition.

*Oils containing Oxygen.*—These are numerous; they change in colour, and are analogous to camphor, which is nothing more than an oxide of carbo-hydrogen. By referring to the table, their constitution may be seen.

*Sulphurized Oils; Oil of Black Mustard.*— $C_{32}H_{20}N_4S_5O_5$ . This is obtained from black mustard seed by distillation. It does not pre-exist, but is the result of a reaction between water, a diastase, and a peculiar principle termed *myronic acid*. When pure, it is colourless, has a suffocating smell, a density of 1.015, and boils at  $289^\circ$ . It is soluble in alcohol and ether.

The oils of *onions*, *horseradish*, &c., have not been exactly determined, but they belong to this class.

#### RESINS AND BALSAMS.

*Resins* consist of carbon, hydrogen, and oxygen. The name is applied to those bodies having two or more proximate principles, separable by their different solubilities in alcohol. They are solid, translucent, brittle, have a shining fracture, are yellowish, and have generally both smell and taste. It is said, however, that resins, if pure, should have no colour, smell, or taste. By heating moderately they soften, higher they melt, and still higher they burn, yielding much smoke. They are insoluble in water, soluble in alcohol, ether, and the volatile and fixed oils, and also unite with and are softened by camphor. Resins are also soluble in the alkalis; in fact, resins are, or contain acids, which, uniting with the alkalis, form true and soluble salts. They are supposed to be formed in the plants



from the juices of which they are obtained, by the oxidation of their volatile oils.

*Rosin*.—Common resin, *colophony*, or rosin, is a good example of this class of bodies. It is, as has been seen, the residue from distilling oil of turpentine. It is a mixture of two acid bodies, called *pinic* and *sylvic acids*; the former being the most soluble in alcohol, which enables us to separate them. Their constitution is  $C_{20}H_{15}O_2$ .

Rosin possesses the general properties described in the general remarks.

The other varieties of resin are, *lac*, of which there are three kinds, viz., stick, seed and shell lac; *mastic*, *sandarac*, *dammar resin*, &c., &c. *Dragon's blood* is a deep red resin. *Copal*, another resin, is much used as a varnish, which is made by dissolving it in the melted state in oils. *Amber* is a fossilized resin.

*Caoutchouc* is a principle obtained from many trees and plants. That of commerce is derived from the *Syphila elastica*, a Brazilian tree, which, on being wounded, exudes a milky juice, which is then poured on clay moulds and smoked. When pure, caoutchouc is tough, whitish, elastic, has no smell or taste, is insoluble in alcohol, but soluble in ether and volatile oils, which latter, however, do not yield it in its original state. Naphtha, however, dissolves it, and leaves it unchanged. It is also soluble in chloroform; it softens and melts by heat, and never gains its original condition.

*Gutta percha* is a substance resembling caoutchouc very much. It is the concrete juice of a tree growing in Borneo. When pure it has neither odour nor taste. At a high temperature it can be moulded into any shape, and it becomes solid again on cooling. It softens at  $160^\circ$ , is insoluble in alcohol, water, weak acids, and alkalies; but is soluble in

ether, volatile oils, bisulphuret of carbon, and chloroform. It was introduced to notice in 1842.

*Balsams* are natural mixtures of a resin, a volatile oil, and benzoic or cinnamic acid, or both. The most common are *balsam of Peru*, and *Tolu*, and gum benzoin.

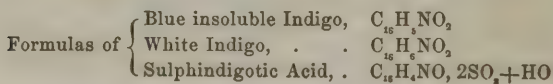
## SECTION IX.

### EXTRACTIVE AND COLOURING MATTERS.

CONCERNING extractive matters, as yet absolutely nothing is known. They are got by treating vegetable products with water and alcohol, and are of various colours. They are modified by temperature, oxygen, air, &c., but as yet no clue to their ultimate constitution has ever been discovered. Even diastase has never been separated, and its existence is only inferred. As a general rule, however, they contain carbon, hydrogen, nitrogen, oxygen, and water.

*Colouring Matters.*—These are very important in relation to the arts. They are all of vegetable origin, except cochineal.

*Indigo.*—This is the product of different species of the *Indigofera*. The leaves are placed in water and allowed to ferment; a yellow substance is dissolved out, which, by contact of the air, is oxidized and becomes deep blue. The dye does not pre-exist as a blue colour in the plant; it is only the result of oxidation. Pure indigo is insoluble in water, alcohol, oils, dilute acids, and alkalis, but is soluble in strong sulphuric acid, constituting *sulphindigotic acid*. To make this, 1 part of indigo is dissolved in 15 parts of sulphuric acid.



*Carbazotic Acid* is procured by the action of nitric acid on indigo; it crystallizes in white scales, is bitter, stains the skin yellow, and explodes when heated. Its formula is  $C_{12}H_2N_3O_{13}$ .

*Litmus*.—This is a red colouring matter, obtained from lichens. The chemist employs it in the blue state as a test for acids, by which it is reddened. The blue colour of the litmus used thus, results from the action of an alkali, generally ammonia, on the proper colour of the lichen; hence, when an acid is added to litmus paper, it only neutralizes the alkali, and restores the natural colour of the litmus.

*Cochineal*.—This is an insect which lives on the cactus. Its dried body yields to water and alcohol a magnificent colouring matter, which is precipitated by alumina. Its composition is unknown.

*Madder* is the root of the *Rubia tinctorum*. A red colouring matter exists in the root called *alizarine*, which is soluble in alcohol, but insoluble in water. By analysis it is found to be  $C_{37}H_{12}O_{10}$ .

*Logwood* contains a purple principle, which has been called *hematoxyline*.

*Quercitron*, *Fustic*, *Saffron*, and *Turmeric*, furnish yellow dyes.

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## SECTION X.

### NEUTRAL NITROGENIZED BODIES.

#### PROTEIN GROUP.

Albumen,	Pepsin, or	Salivin,
Fibrin,	Gasterase, or	Globulin,
Casein,	Animal Diastase,	Crystalline.

*Protein*.— $C_{48}H_{36}N_6O_{12} + P + S$ . Symbol Pt. When any of the bodies included in the protein group is dissolved in a caustic alkali, and then treated with an excess of acid (generally acetic), a copious snow-white precipitate falls, which is called protein. Mulder supposed that this body was a substance *sui generis*, and that it existed in different combinations with sulphur and phosphorus, constituting the so-called protein compounds. Liebig denied this, and said, that the protein existed in these as phosphamides and sulphamides, bodies analogous to chloramide.

Protein is tasteless, insoluble in water and alcohol, but soluble in acetic acid, and in solutions of the alkalies. It acts both as an acid and a base.

*Albumen*.—There are two varieties of albumen, viz., that from serum, the formula for which is  $Pt_{10} + S_2P$ ; and that from eggs, whose formula is  $Pt_{10} + SP$ . It is found in serum of blood and in eggs, in a state of solution; but in its purest form it is insoluble in water. It is made soluble by the presence of soda. It may be dried and kept any time without change, and have all its original properties restored by merely adding warm water.

Albumen coagulates by heat and becomes solid. It is also coagulated by the mineral acids, by creasote, by salts, by tannic acid, &c., &c.

It is supposed to exist in the blood and in eggs as the albuminate of soda.

*Fibrin*.— $Pt_{10} + SP$ . This exists in two states, viz., solid, and in solution. In the former condition we find it in muscle, in the latter in the blood. It is obtained pure by whipping fresh-drawn blood with a bundle of sticks; the fibrin attaches itself to the sticks, and is easily washed. It differs from albumen by coagulating spontaneously. It constitutes from  $\frac{1}{1000}$  to  $\frac{5}{1000}$  of the blood.

*Casein*.— $Pt_{10} + S$ . This is found in milk, blood, pus and

tubercle. It is a very important body, because it forms the nitrogenized element of the food of all the young mammalia. Casein is obtained by warming fresh milk with sulphuric acid, washing the product and removing the acid by an alkali. It is white, curdy, insoluble in water or alcohol, but made soluble by the smallest portion of potassa or soda. It does not coagulate by boiling, which property serves to distinguish it from albumen. It coagulates in the milk spontaneously, if the milk is permitted to stand some time, and it is also coagulated by the gastric mucous membrane. This is due to the conversion of the sugar of milk into *lactic acid*, which, as soon as it is developed, coagulates the caseine, and the milk is resolved into two portions, the curd and the whey. A slight elevation of temperature hastens the process. Casein is also coagulated by the acids.

*Pepsin or Gasterase*.—This exists in the epithelial cells of the mucous membrane of the stomach. It is held in solution by the acids of the stomach, and thus constitutes the gastric juice. To get it, dissolve the mucous membrane of the stomach in acidulated water, add subacetate of lead; the pepsin is precipitated with lead and albumen; remove the lead by sulphuretted hydrogen, and the albumen by heat, and the pepsin is left.

*Salivin or Animal Diastase* is found in the saliva. It serves to convert the amylaceous portion of our food into glucose during the process of digestion.

*Globulin* is found in the blood corpuscle.

*Crystalline* is found in the crystalline lens of the eye.

#### GELATIN GROUP.

##### COLLIN AND CHONDRIN.

*Collin* is obtained from skin, ligaments, areolar tissue, &c.  
*Chondrin* is got from the permanent cartilages.

*Gelatin* is obtained by boiling these bodies in hot water for some time; solutions are obtained, which acquire a soft, tremulous consistence. When this is cut in thin plates and exposed to the air, it shrinks, becomes hard, dry, and transparent, and in this state is called glue. Gelatin is soluble in water; its solution is precipitated by alcohol and corrosive sublimate. With tannic acid it gives a copious white precipitate, insoluble in water, and incapable of putrefaction. This is formed in tanning.

#### NEURINE.

*Neurine*, the material of the nervous tissue, is a very complex structure; 20 per cent. of it is solid material, consisting of albumen, fats (which are margaric, cerebrie, and oleophosphoric acids, and cholesterine), osmazome, phosphates of lime, magnesia, iron, &c., &c.

#### HÆMATIN.

*Hæmatin* is found only in the blood corpuscle of red blood. It is loosely associated with globulin, and is easily washed out by water. When pure it is reddish-black, solid, has a metallic lustre, and is insoluble in alcohol, ether, and water, but is readily made so by the addition of a caustic alkali. It was supposed, at one time, to be the carrier of oxygen in the blood; but this has been proved untrue.

#### TABLE OF THE CONSTITUENTS OF NORMAL URINE.

Sp. Gr. 1.018 to 1.020.

Mucus.	Soda.
Uric and Lithic Acids.	Potassa.
Urea.	Lime.
Phosphoric Acid.	Magnesia.
Sulphuric Acid.	Silica.
Lactic Acid.	Water.
Ammonia.	



URINARY DEPOSITS.

Yellow or Brown, . . .	{ Urate of ammonia, Colouring matter, Earthy phosphates, Urate of soda.
Lateritious, . . .	{ Alkaline urates, Colouring matter, Murexide.
Pink, . . . . .	Urate of ammonia and murexide.
Phosphatic, . . .	{ Phosphate of ammonia and magnesia, Phosphate of lime.
Red Crystals, . . .	Uric acid.
Also, oxalate of lime, blood, mucus, cystine, &c., &c.	

TABLE OF URINARY CALCULI.

Lithic or Uric Acids,	{ Uric acid, Urate of ammonia, Urate of soda, Urate of lime, &c.
Phosphatic, . . .	Ammonio-magnesian phosphate.
Fusible, . . . . .	{ Ammonio-magnesian phosphate and phosphate of lime.
Mulberry, . . . . .	{ Oxalate of lime, Oxalate of ammonia.



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